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RESEARCH NEEDS FOR THE POTABLE REUSE OF MUNICIPAL WASTEWATER

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MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY

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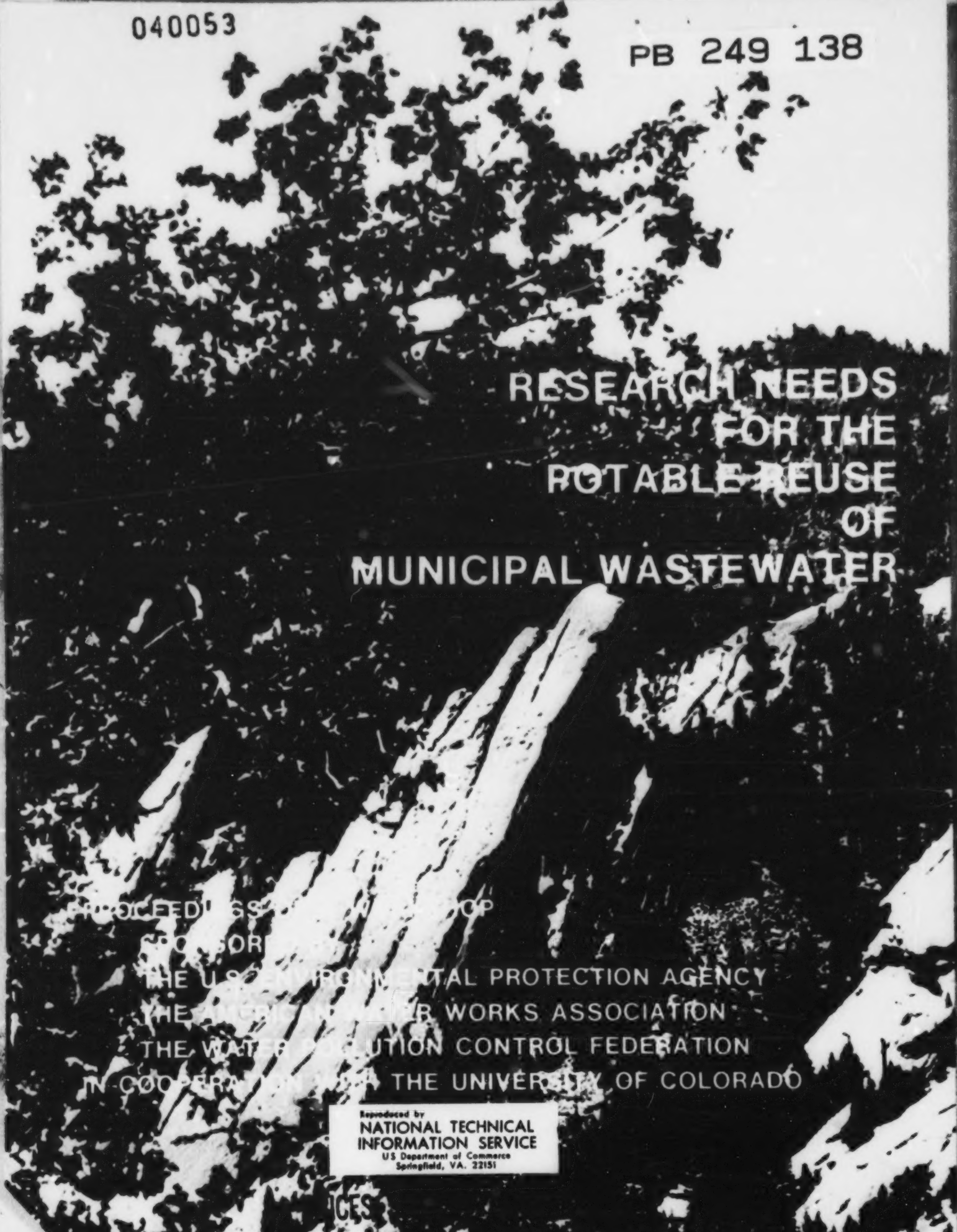

RESEARCH NEEDS FOR THE POTABLE REUSE OF MUNICIPAL WASTEWATER

PROCEEDINGS OF A WORKSHOP
SPONSORED BY
THE U.S. ENVIRONMENTAL PROTECTION AGENCY
THE AMERICAN WATER WORKS ASSOCIATION
THE WATER POLLUTION CONTROL FEDERATION
IN COOPERATION WITH THE UNIVERSITY OF COLORADO

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The objective of the workshop was to define and establish priorities for research needed to develop confidence in the reuse of wastewater for potable purposes. This objective was accomplished by bringing together 92 select persons concerned with wastewater reuse to discuss and identify research gaps in the areas of health effects, treatment technology, and the socio-economic considerations of potable reuse. This identified research will serve as a basis for future EPA projects.

The workshop was jointly sponsored by the Environmental Protection Agency (EPA), the Water Pollution Control Federation (WPCF), the American Water Works Association (AWWA), and was held in cooperation with the University of Colorado in March 1975, at the Boulder, Colorado campus.

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RESEARCH NEEDS
FOR THE
POTABLE REUSE OF MUNICIPAL WASTEWATER

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U.S. Environmental Protection Agency
American Water Works Association
Water Pollution Control Federation
in cooperation with the
University of Colorado

March 17-20, 1975, Boulder, Colorado

Edited By:

K. Daniel Linstedt
Edwin R. Bennett
University of Colorado

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Project Officer

John N. English
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment---air, water, and land. The Municipal Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources

This Proceedings contains the results of a Workshop that was held to identify research needs for the reuse of municipal wastewater for potable purposes. Identification of needed research is a necessary first step in developing the technology to recycle resources and protect the environment.

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Environmental Protection Agency

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J. M. Smith, Environmental Protection Agency
E. F. Spitzer, American Water Works Association
P. Tobin, Environmental Protection Agency

PREFACE

Water reuse is not a new concept in that it has been practiced for many years for such non-potable uses as irrigation, recreation, and industrial purposes. However, it has recently become apparent that sound management of water resources must include consideration of the potential for indirect or direct reuse of high quality treated wastewaters as part of domestic supply waters. Where water development costs and legal constraints are making sources of raw water difficult to acquire, wastewater reuse is increasingly being considered as a potential alternative water source. While present treatment technology has proven adequate to provide a suitable product water quality for many of the non-potable reuse applications, this is certainly not the case for domestic wastewater reuse. Additional research is necessary before direct potable reuse can be permitted.

The Water Pollution Control Federation and the American Water Works Association recently issued a joint resolution that urged the Federal government to support a massive research effort to develop needed technology and evaluate potential health problems related to recycling of wastewaters to domestic water supplies. These organizations underscored the "lack of adequate scientific information about possible acute and long-term effects on man's health from such reuse," and also noted that "the essential fail-safe technology to permit such direct reuse has not yet been demonstrated." The resolution identified the need for an "immediate and sustained multidisciplinary, national effort to provide the scientific knowledge and technology relative to the reuse of water for drinking purposes in order to assure the full protection of the public health."

Public Law 92-500, the "Federal Water Pollution Control Act Amendments of 1972," recognized the potentially large benefit to be realized if wastewaters can be renovated for reuse applications. It authorized EPA to make grants for demonstrating advanced waste treatment and water purification methods, and required that the Administrator conduct an accelerated effort to develop, refine and achieve practical application of advanced waste treatment methods for reclaiming and recycling water.

Likewise, the new Safe Drinking Water Act also contained mandates of importance with regard to renovation and recycling of wastewaters. Specifically, it authorized a development and demonstration program to (1) demonstrate new or improved technology for providing safe water supply to both urban and rural areas, and (2) to investigate and demonstrate health implications involved in the reclamation, recycling, and reuse of wastewaters for drinking and related uses, and to demonstrate processes and methods for the safe and aesthetic preparation of such waters. There exists, therefore, a strong and clear mandate for research, development, and demonstration of reliable, cost-effective technology for reclaiming and recycling wastewaters for beneficial uses.

The Research Needs workshop which is summarized in this document represents an initial step in the formulation of a unified research program aimed at developing confidence in potable reuse of waste water. The workshop was jointly sponsored by the United States Environmental Protection Agency, American Water Works Association, and the Water Pollution Control Federation, and was held on March 17-20, 1975, in Boulder, Colorado. It has provided a forum for assembling specific input relative to the wide range of research needs associated with potable reuse. We trust that this input will lead to the development of a coherent and effective research effort on domestic wastewater reuse.

K. Daniel Linstedt
Cochairman, Municipal
Wastewater Reuse
Research Needs Workshop

Edwin R. Bennett
Cochairman, Municipal
Wastewater Reuse
Research Needs Workshop

John N. English, Member
Organizing Committee
Municipal Wastewater
Reuse Research Needs
Workshop

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WORKSHOP SUMMARY

The reuse of wastewater offers many potential benefits in terms of both water pollution control and augmentation of existing natural water resources. This reuse may take a number of forms depending upon the local conditions and the quality of the reuse source. Included among these potential uses are irrigation, recreation, industrial applications, and groundwater recharge. In order to maximize the benefits derived from wastewater reuse it would be desirable to have the flexibility to use this water for all purposes, including direct potable reuse.

In order to accomplish this direct reuse of water in the most effective manner, it is necessary to first clearly define the research and development that is needed, and then to establish priorities for implementation of this program. Toward this end, ninety-two participants attended the "Municipal Wastewater Reuse Research Needs Workshop". To insure a broad coverage of all viewpoints, the participants represented government regulatory and research agencies, universities, operating engineers and managers of large treatment systems, consulting engineering firms, and equipment manufacturers. The first day of the workshop was devoted to the presentation and discussion of current research and demonstration activities related to treatment technology and health effects associated with current and proposed water reuse applications. From these presentations it was apparent that there is a limited, but expanding, amount of water reuse being practiced at the present time for non-potable purposes. However, there is increasing interest developing to accomplish this reuse on a much broader scale. Likewise, at the present time there are only a limited number of municipalities incorporating potable reuse into their resource planning. These municipalities must have assurance of the potability of reuse water prior to implementing their reuse plans. The time frame indicated for providing the technology development and health effects evaluation necessary to provide this assurance was indicated to be in the range of 10-15 years, assuming that a comprehensive research and demonstration effort is initiated in the very near future.

The second and third days of the meeting were devoted to workshop discussions directed at the specific research needs in each of the following subject areas: 1) treatment reliability and effluent quality control for potable reuse, 2) wastewater treatment for potable reuse, 3) health effects of potable reuse associated with inorganic pollutants, 4) health effects of potable reuse associated with viruses and other biological pollutants, 5) health effects of potable reuse associated with organic pollutants, and 6) socio-economic aspects of potable reuse. A number of points and research needs were discussed during these workshop sessions which were common to several of the workshop groups. These common points of discussion included:

1. It was the general consensus of the participants in the workshop that the research needs identified for direct potable reuse should be applied equally to the indirect reuse of wastewater, which has been practiced for some time. This recommendation applies to the effluent quality control and reliability studies which were identified as well as to the toxicological and epidemiological study suggestions.

2. Research is needed to identify the contaminants which are currently present in domestic water supplies and to evaluate the current water treatment processes to determine their effectiveness in controlling these contaminants. This type of characterization will serve as the basis for assessing the effect of various levels of indirect reuse, as well as providing some insight into unit process selection for water renovation. Similar evaluation of candidate water renovation processes should be performed to assess the effectiveness of these processes and to characterize the product water for comparison with existing drinking water supplies.

3. Development of rapid, sensitive, and accurate testing procedures is required for the inorganic, organic, and biological constituents in wastewater. In line with this, indicator parameters must be identified in each of these areas which can be used for continuous, on-line monitoring of product quality.

4. Toxicological studies are needed involving the application of in vitro methods to screen classes of wastewater contaminants and their concentrates. This screening should involve several in vitro systems including bacterial and cell culture systems. Animal toxicity testing should be used to validate such techniques where appropriate.

5. Consideration should be given to a collaborative effort with the WHO International Reference Center on Community Water Supplies involving retrospective and prospective epidemiologic surveys of population groups exposed to indirect wastewater reuse. The aim would be to determine whether there are any detrimental health effects resulting from such long-term exposure.

6. The workshop recognized the strong need for improvement in the exchange of information relative to reuse, both within the United States and throughout the world. This was identified as being particularly important as it relates to new developments in analytical methodology, treatment technology, and health effects research. Channels of communication should be established for rapid dissemination of this information.

In addition to the common areas of research need which were indicated, each workshop group identified research and development needs which were specific to the assigned workshop. Highlights from the research needs cited by each of the six groups are as follow.

Several research areas were indicated by the Treatment Reliability and Effluent Quality Control group as being necessary for defining treatment design goals. These involved establishing water quality standards for potable reuse, requirements for fail/safe reliability, and allowable limits of product quality variability. With the establishment of these goals and limits the group outlined a set of research needs aimed at determining the equipment and management requirements for providing the required renovation system reliability.

The Wastewater Treatment group identified a large-scale demonstration effort as being among the most important treatment needs. The purpose of this effort would be to characterize the long-term effectiveness and reliability of various alternative treatment systems for producing a potable quality product. In evaluating these systems, the efficiency of removal for undesirable wastewater constituents would be a necessary criteria, as would the energy requirements, system costs, overall reliability, and residue disposal considerations. Additional work was indicated in the development of cost effective processes for disinfection, trace organic removal, nitrogen removal, and demineralization.

A balanced use of epidemiological and toxicological research was indicated as being extremely important in ascertaining the Health Effects of Potable Reuse Associated with Inorganic Pollutants. The epidemiological program which was recommended included an assessment of the relationship between current water quality and the incidence and prevalence of chronic diseases, as well as a determiation of the body burdens of inorganic substances. The strategy called for in the toxicological studies involved *in vitro* screening of concentrated toxicants, animal toxicity testing, and population dose estimation.

The workshop group dealing with Health Effects of Potable Reuse Associated with Viruses and Other Biological Pollutants highlighted the development and evaluation of rapid and relatively simple methods for detection of viruses having major public health significance as being among the areas warranting extensive research. This was coupled to a high priority for determining the degree and mechanisms of removal and inactivation of viruses in reclaimed waters.

The workshop group on Health Effects of Potable Reuse Associated with Organic Pollutants recommended that the EPA develop a viable and visible program to assess the potability of reused water. The program should have a program manager charged with preparing a critical path analysis, with time and monetary requirements, for evaluating the health effects of potable reuse. In addition, as part of a toxicity testing program the group identified the need for an assessment of the interaction of pollutants to determine the importance of synergistic effects on the toxicity of organic compounds which might occur in renovated wastewater.

Among the recommendations developed by the working group on Socio-Economic Aspects of Potable Reuse was a need to identify the extent to which the U.S. population is presently being supplied former wastewater as a part of the raw water supply. An extension of this need involved the suggestion that a public education program be undertaken to indicate the true picture concerning the current practice of indirect water recycling. It was also recommended that an in-depth investigation of potential reuse cost-effectiveness be performed at several specific U.S. locations of varying characteristics.

In conclusion, the Workshop has made it apparent that there are many specific research needs related to treatment technology and reliability, health effects, and socio-economic considerations for potable water reuse. The importance of proceeding with the accomplishment of this research is related not only to the recognized need for future direct reuse, but also because of the insight these investigations will provide concerning our current supply sources, many of which are currently influenced by upstream discharges of municipal and industrial wastewaters.

WORKSHOP OBJECTIVES

Donald P. Dubois, Deputy Regional Administrator
Region VIII, Environmental Protection Agency

In looking over the agenda for this workshop, I have been impressed with the scope and organization of the program, and with the impressive credentials of the international group of participants and speakers that have been assembled. I am confident that the nature of this program and the quality of the participants will allow us to achieve our objective, which is to define and establish the priorities for research needed to develop confidence in the reuse of wastewater for potable purposes.

I think that is a most worthy objective for this conference. I suppose we could ask why it is important that we achieve this objective. I suspect that many of you who work in this field on a daily basis know better than I, but from my own perspective, I think the one reason it is important to achieve this objective is because we already are reusing water. For the most part this reuse is not intentional or direct, but relates to the wastes discharged through our major river systems, and the subsequent downstream use of that water for drinking and potable purposes.

Over a long period, the Public Health Service, now EPA, has developed a very strong commitment to define what is in water that is being used in the lower portions of river systems and whether or not these constituents are harmful to health and welfare. For those that are harmful the agency has sought to develop means to remove these constituents or render them less harmful. I think the classic example of the chlorinated organics in the New Orleans water supply, which came to the fore here in the last few months, illustrates what I am talking about in that context.

Looking again from my perspective here in the Rocky Mountain-Prairie Region, I think it is critically important that we begin to directly reuse water wherever possible. Particularly in this part of the country, we are running short of unused or pristine water supplies. There are many competing uses for those water supplies in terms of municipal purposes, industrial, agricultural, recreational, and so forth. The environmental impact of developing some of these pristine sources can be, and often is, undesirable. This is evidenced by disruption of stream flows, alteration of the ecology of the stream system and fisheries, and by the concentrating effect on salinity and other constituents that can result from depletions of stream flows in the headwater areas. In addition, the cost of developing these upstream mountain water supplies is becoming prohibitive in many cases.

All of these reasons combine to say that we must expand our emphasis on developing means of increasing water reuse. However, I would introduce a note of caution at this point. It is clear that we must know what we are doing before we rush into a direct reuse program for potable purposes. I think we must balance the drive to define reuse techniques with a program to develop answers to the problems associated with reuse so that we can be confident that the benefits which we perceive from reuse will not be offset by possible harmful health effects. I think that is why you are all here; to chart a course for a research and development program that will identify the benefits, and most importantly, will define and reduce the risks of water reuse.

Congress has recognized the need for this kind of research and development in the Federal Water Pollution Control Act of 1972, and the Safe Drinking Water Act of 1974, both of which give EPA strong authority for research into practically all phases of waste treatment, water treatment, and reuse. I think your task really boils down to helping EPA define our research priorities so that we can build on the research work that has already been underway for many years and direct it more into the area of potable water reuse, in order to better define the risks and what we can do about them. I hope also that this workshop will identify what the other institutions--the universities, the consulting engineers, the municipalities--can do as their part of the responsibility. It certainly is not all EPA's responsibility.

I do hope you have a successful conference. I am confident that you will.

OVERVIEW OF WASTEWATER REUSE AND EPA RESEARCH STRATEGY

F. M. Middleton
Deputy Director
National Environmental Research Center
Environmental Protection Agency
Cincinnati, Ohio 45268

ABSTRACT

Water reuse is a common fact of life. Water shortages and the recent recognition in the United States of the need to conserve water has focused attention upon the value of more intentional reuse. Planners recognize the need for a hierachy of water use in the community. All water need not be of the same quality. And the wastewater of a community should be considered a resource.

Wastewater reuse is being specifically recognized by recent legislation. Public Law 92-500, The "Federal Water Pollution Control Act Amendments of 1972", calls for research and facilities construction to permit reuse. Public Law 93-253, The "Safe Drinking Water Act", passed in December 1974 allows for grants to investigate and demonstrate health implications involved in reclamation, recycling and reuse of wastewaters to prepare a safe and acceptable drinking water. The American Water Works Association and the Water Pollution Control Federation have issued a joint statement in support of appropriate reuse.

Municipalities on an annual basis use about 10 trillion gallons of water and wastewater return amounts to 8 trillion gallons. Present wastewater usage for specific purposes such as irrigation and cooling amount to only 134 billion gallons or less than 2% of the available flow. Much of the waste flow can be put to productive use.

A great deal of research in EPA is directed toward some facet of wastewater reuse. A major effort is now needed to embark upon a long-term integrated program to permit wastewater reuse for any purpose including to supply drinking water. Some states and major municipalities are already working on a variety of reuse projects. Our combined programs should lead us to a sound base of science and technology that will ensure safety and gain the public confidence for full-scale water reuse. The technology for preparing water of any quality is well advanced. Needed is better knowledge on the level of residues that remain and their possible health effects. Social and economic factors will need additional research.

INTRODUCTION

Abundant supplies of clean surface and underground waters in the United States have been taken for granted until recent years. Severe contamination of many surface supplies has occurred. Increasing instances of groundwater contamination are being found. Thus, our relatively fixed volume of water may become less and less usable. Adequate pollution control measures must be taken and conservation and reclamation of resources must become the rule.

Water has always been used and reused by man. The natural water cycle, evaporation, and precipitation is one of reuse. The return of wastewaters to the streams and lakes of the country is a fact of life. The unplanned reuse of wastewaters is not new. The planned reuse of wastewaters for beneficial purposes has been done in some areas for many years, but it is here that we need to concentrate our efforts for far greater use of our wastewaters. The purpose of this seminar is to set the research needs and objectives to move forward in the planned wastewater reuse area.

The quality and quantity of wastewaters produced by the community depend upon such factors as the source of supply, population density, industrial practices, and even the attitudes of the local population. The quality of the environment can be improved by reducing pollution at the source, providing adequate treatment of the wastewaters, and by recycling and reusing wastewater. Public support and some change in social behavior will be required in most instances.

DEFINITIONS

Since there are many different types of wastewater reuse and the term "reuse" has different meanings to different people, the following definitions will be used for this Workshop:

Municipal Wastewater - The spent water of a community, consisting of water-carried wastes from residences, commercial buildings, and industrial plants and surface or groundwaters that enter the sewerage system.

Advanced Waste Treatment - Treatment systems that go beyond the conventional primary and secondary processes. Advanced waste treatment systems may include biological processes, the use of chemicals, activated carbon, filtration, or separation by membranes.

Indirect Reuse - Indirect reuse of of wastewater occurs when water already used one or more times for domestic or industrial purposes is discharged into fresh surface or underground waters and is used again in its diluted form.

Direct Reuse - The planned and deliberate use of treated wastewater for some beneficial purpose such as irrigation, recreation, industry, prevention of salt water intrusion by recharging of underground aquifers, and potable reuse.

Potable reuse can be further divided into two categories as follows:

Indirect Potable Reuse - The planned addition of treated wastewater to a drinking water reservoir, underground aquifer, or other body of water designed for potable use that provides a significant dilution factor.

Direct Potable Reuse - The planned addition of treated wastewater to the headworks of a potable water treatment plant or directly into a potable water distribution system.

OFFICIAL SUPPORT FOR WASTEWATER REUSE

The role of the U.S. Environmental Protection Agency (USEPA) and its predecessor organizations in wastewater reuse has been stated in various acts. Public Law 87-88 passed in 1961 amending the Federal Water Pollution Control Act directed the Secretary (at that time of Health, Education, and Welfare) "to develop and demonstrate practicable means of treating municipal sewage and other water-borne wastes to remove the maximum possible amounts of physical, chemical, and biological pollutants in order to restore and maintain the maximum amount of the Nation's water at a quality suitable for repeated reuse."

This Act gave impetus to the Advanced Waste Treatment Research Program, which began in 1960. The objective of this national program is to conduct research that will develop new and improve existing wastewater treatment processes and ultimate disposal technology, thus permitting maximum removal of contaminants and repeated reuse of the Nation's waters.

Public Law 92-500, the "Federal Water Pollution Control Act Amendments of 1972", recognizes the potentially large benefit to be realized if wastewaters can be renovated for reuse applications. Sections 201 (b), 201 (d), and 201 (g) (2) (B) clearly require 1. that EPA provide for the application of best practicable waste treatment technology, including reclaiming and recycling of water; 2. that construction of revenue producing facilities providing for reclaiming and recycling be encouraged; and 3. that works proposed for grant assistance, to the extent practicable, allow for the application of technology at a later date which will provide for reclaiming and recycling of water. Section 105 (a) (2) authorizes EPA to make grants for demonstrating advanced waste treatment and water purification methods, and Section 105 (d) (2) requires that the Administrator conduct on a priority basis an accelerated effort to develop, refine, and achieve practical application of advanced waste treatment methods for reclaiming and recycling water and confining pollutants.

The Safe Drinking Water Act of 1974 (Section 1444) also contains mandates of importance with regard to renovation and recycling of wastewaters. Section 1444 authorizes a development and demonstration program to: demonstrate new or improved technology for providing safe water supply to the public; investigate and demonstrate health implications involved in the reclamation, recycling and reuse of wastewaters for the preparation of safe and acceptable drinking water.

There exists, therefore, a strong and clear legislative mandate for research development and demonstration of reliable, cost-effective technology for reclaiming and recycling wastewaters for beneficial uses. A major beneficial use is the supplementation of domestic water supplies.

The Water Pollution Control Federation (WPCF) (1) and the American Water Works Association (AWWA) issued a joint resolution that urged the Federal Government to support a massive research effort to develop needed technology. These organizations underscored the "lack of adequate scientific information about possible acute and long-term effects on man's health from such reuse", and also noted that "the essential fail-safe technology to permit such direct reuse has not yet been demonstrated." The resolution recognizes the need for an "immediate and sustained multi-disciplinary, national effort to provide the scientific knowledge and technology relative to the reuse of water for drinking purposes in order to assure full protection of the public health."

The USEPA in a policy statement on water reuse dated July 7, 1972, supports and encourages the development and practice of successive wastewater reuse. EPA does not currently support the direct interconnection of wastewater reclamation plants with potable water systems.

SPECIFIC CONSIDERATIONS GOVERNING REUSE

The reuse of treated effluents is most applicable where large volumes of water are used and the wastes are not highly contaminated. The location of the treatment plant and the possible transport of the renovated water are important considerations. A wastewater renovation plant need not always be located at the same place as the municipal wastewater disposal plant, nor should the renovation process be dependent upon treating the total flow. Treatment processes work most efficiently and economically when dealing with a steady flow of wastewater rather than with the irregular flow normally experienced from urban sources. This condition can be obtained by withdrawing only a part of the urban wastewater; this is depicted in Figure 1, which shows how water renovation and reuse can be planned to best advantage in the community.

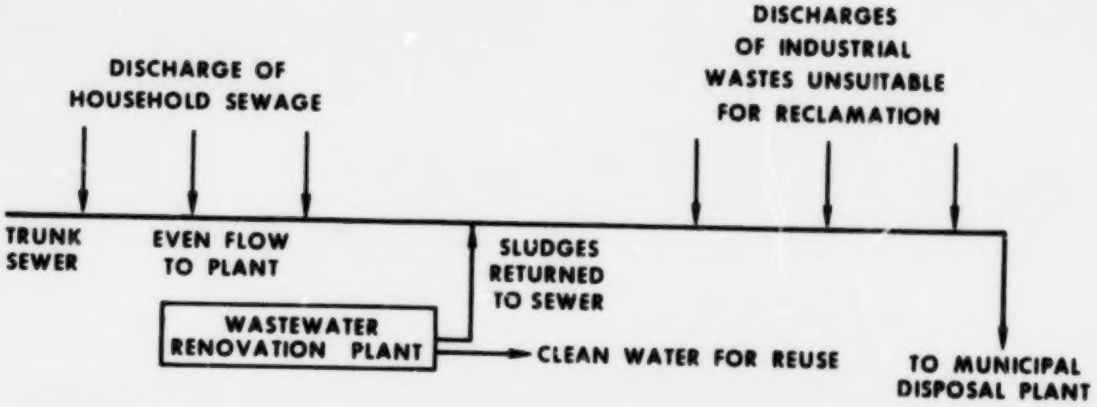
VOLUME OF WASTEWATERS AVAILABLE IN MUNICIPALITIES

Municipalities on an annual basis use about 10 trillion gallons of water, and wastewater return amounts to 8 trillion gallons. Present wastewater usage for specific purposes is shown in Table 1.

As can be seen from the Table, only 136 billion gallons, or less than 2% of the available flow, is used on a planned basis. Much of the waste flow can be put to productive use. Such uses can go a long way in conserving scarce clean water sources.

STANDARDS FOR WASTEWATER REUSE

To ensure the safety of water supplies, standards have to be applied. Standards for drinking water have been available for many years. Although national standards may be set for drinking water, the qualities of river-water, industrial effluents, and reused wastewater are the responsibility of the local controlling authority. Even so, the standards set must take into account the possible transport of pollutants across state borders or the effects of discharges on downstream water users. Standard setting is a most difficult and critical job, with important economic implications. Standards must be given the force of law, and an authority must be created to ensure that they are observed.


DISCHARGE OF
HOUSEHOLD SEWAGE
DISCHARGES
OF INDUSTRIAL
WASTES UNSUITABLE
FOR RECLAMATION
TRUNK
SEWER
EVEN FLOW
TO PLANT
SLUDGES
RETURNED
TO SEWER
WASTEWATER
RENOVATION PLANT
CLEAN WATER FOR REUSE
TO MUNICIPAL
DISPOSAL PLANT

The diversion of wastewater from the trunk sewer to the wastewater renovation plant should be chosen at a point where it is known that the trunk sewer contains only household sewage.

FIGURE 1. Simplified Wastewater Reuse Scheme*

*From World Health Organization Technical Report No. 517 (1973)

TABLE 1. Water Reuse in the United States

Type	Volume in 1971	No. of Plants
Irrigation and agriculture	77 bg	338
Industrial	54	14
Recreational	3	5
Non-potable domestic	<1	1
*Groundwater augmentation	<1	8

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*Estimated from information in EPA publication EPA-660/2-73-006b "Wastewater Treatment and Reuse by Land Application" - Vol. I & II

Standards governing the quality of water in rivers and lakes are becoming common. Some countries have, and others are formulating, standards applicable directly to effluents, though few countries yet have standards for the planned reuse of treated wastewater. As wastewater reuse grows, it is important that standards be set for specific reuse purposes.

As wastewater - treated or untreated - has been reused in agriculture for a fairly long time, some countries have developed standards for this purpose. A summary of some representative standards for the use of renovated water in agriculture is given in Table 2.

TABLE 2. EXISTING STANDARDS GOVERNING THE USE OF RENOVATED WATER IN AGRICULTURE*

	California	Israel	South Africa	Federal Republic of Germany
Orchards and vineyards	Primary effluent; no spray irrigation ; no use of dropped fruit	Secondary effluent.	Tertiary effluent, heavily chlorinated where possible. No spray irrigation.	No spray irrigation in the vicinity.
Fodder, fibre crops, and seed crops	Primary effluent ; surface or spray irrigation.	Secondary effluent, but irrigation of seed crops for producing edible vegetables not permitted.	Tertiary effluent.	Pretreatment with screening and settling tanks. For spray irrigation, biological treatment and chlorination.
Crops for human consumption that will be processed to kill pathogens	For surface irrigation, primary effluent. For spray irrigation, disinfected secondary effluent (no more than 23 coliform organisms per 100 ml).	Vegetables for human consumption not to be irrigated with renovated wastewater unless it has been properly disinfected ($<$ 1000 coliform organisms per 100 ml in 80% of samples).	Tertiary effluent.	Irrigation up to 4 weeks before harvesting only.
Crops for human consumption in a raw state	For surface irrigation, no more than 2.2 coliform organisms per 100 ml. For spray irrigation, disinfected, filtered wastewater with turbidity of 10 units permitted, providing it has been treated by coagulation.	Not to be irrigated with renovated wastewater unless they consist of fruits that are peeled before eating.		Potatoes and cereals—irrigation through flowering stage only.

*From World Health Organization Technical Report No. 517 (1973)

DOMESTIC REUSE

In any reuse application there are a number of points to consider. One very important question is whether the reuse will result in multiple recycle. Multiple recycle produces a buildup of refractory materials, especially inorganic ions, and may require the use of demineralization or other specialized processes. In-plant reuse of industrial water, where actual consumption is small, may lead to a high degree of recycle. On the other hand reuses of municipal wastewater, except for domestic reuse, probably would not lead to multiple recycle. Even in the case of domestic reuse there is not likely to be total recycle. The reason is that less water is ordinarily found arriving at the wastewater treatment plant than is supplied to the municipal water system. Such losses do occur and are quite large in warm, dry areas where domestic reuse is likely to be most widely practiced. In the United States, it is estimated (2) that these losses range from less than 20% in humid areas to about 60% in arid areas. Parkhurst et al., (3) point out, based on experience in the Los Angeles area, that less than 50% of a water supply would be available for reuse. The disadvantage of these large losses is the need for a substantial additonal fresh water source. The advantage is that the steady state mineral concentration is reduced. As a result, the degree of demineralization may be reduced substantially below that needed if there were no losses. Also, there is the flexibility of demineralizing either the renovated wastewater or the supplementary water source; there may be advantages to demineralizing the supplementary source.

Another consideration in reuse is the character of the wastewater entering the treatment plant, especially with respect to industrial pollutants. Care must be used to exclude materials that would be detrimental to the reuse application. This is especially true for domestic reuse, but also applies to less sophisticated reuse applications. These materials may not be those usually considered toxic. Ordinary salt brines would be undesirable, for example, if demineralization were being carried out on the renovated wastewater. In Los Angeles County, a survey of the sewer systems has been made to determine how much of the available wastewater has potential for reuse. Waters having heavy metal contamination or high total dissolved solids were considered unacceptable. A similar survey will be necessary for other municipalities planning extensive reuse.

Another point that must be considered is distribution of the renovated water. A multiplicity of piping systems, each one containing a different quality renovated water, will not usually be practical. There may be a number of large consumers in the vicinity of the treatment plant. This would make distribution simple and inexpensive. If the consumers are widely distributed, however, one piping system in addition to the existing municipal water system is almost certain to be the most that will be economically realistic. The result is that the renovated wastewater must be of a quality to satisfy most of the customers without additional treatment. Treatment such as those necessary for boiler water feed would be excluded, since present practice in water supply has shown that those treatments are more appropriately carried out by the user.

INDIRECT REUSE OF WASTEWATER

A study of a number of rivers, carried out in 1961 by Koenig (4), showed that, at periods of low flow, 3.5% to 18.5% of the water had passed through domestic systems. If the volume of industrial effluents is taken into account, it would be expected that 20% to 40% of the river water at low flow in some areas may be reused water. The lower Rhine River serving as a drinking water source for 6 million people is 40% to nearly 100% sewage effluent depending upon flows. The river Thames, serving as source for two-thirds of the water for London flowing at an average rate is about 14% sewage effluent.

These levels of contamination indicate the increasing need to consider the optimum distribution of purification among the wastewater treatment plant, the river itself (self purification), and the plant that produces potable water. Adequate answers require analysis of the costs and benefits involved. More and more, around the world, "river basin authorities" are taking control over the treatment and discharge of wastewaters, and over the abstraction and treatment of potable waters.

DIRECT REUSE OF WASTEWATERS

Treated wastewater may be deliberately used in a planned way for a variety of purposes, some of which are shown in Figure 2.

A comprehensive survey of demonstrated reuse technology has been made by SCS Engineers (5). A variety of direct and other reuse applications of effluents has been published by the World Health Organization (6).

RESEARCH STRATEGY

A substantial base of science and technology already exists for many wastewater reuse applications. We need now to plan our research to achieve the highest quality water and assure its safety for any use. We expect this Workshop to provide a charted path that can guide workers for several years. Some of the areas to be considered follow:

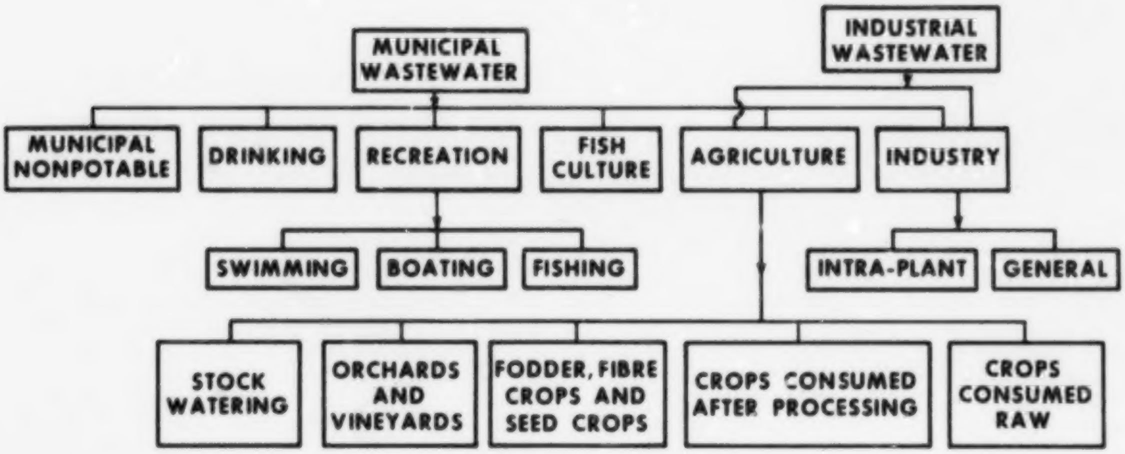
MUNICIPAL WASTEWATER
INDUSTRIAL WASTEWATER
MUNICIPAL NONPOTABLE
DRINKING
RECREATION
FISH CULTURE
AGRICULTURE
INDUSTRY
SWIMMING
BOATING
FISHING
INTRA-PLANT
GENERAL
STOCK WATERING
ORCHARDS AND VINEYARDS
FODDER, FIBRE CROPS AND SEED CROPS
CROPS CONSUMED AFTER PROCESSING
CROPS CONSUMED RAW

FIGURE 2. Intentional Reuse of Wastewater*

***From World Health Organization Technical Report No. 517 (1973)**

HEALTH EFFECTS OF CONTAMINANTS

Full-scale reuse will be inhibited most by questions concerning health effects. We are constantly reminded that very low, but significant, concentrations of toxic chemicals and carcinogens appear in our environment. Often it is only after many years of exposure that the deleterious effects are associated with the cause. How can we improve our ability to screen and predict what is harmful? What concentrations of materials are tolerable in water? Do the harmful materials accumulate in the food chain? In addition to safety for potable purpose, we need information on health effects from body contact, stock watering, irrigation, and fish propagation. Following laboratory studies of pathogenic, toxic, carcinogenic, and teratogenic effects, epidemiological studies will be a necessity.

QUALITY CONTROL OF RENOVATED WATER

Quality control is essential for any water derived from polluted sources, and the more recent the derivation, the more important the quality control. In planning water reuse projects, a positive laboratory testing and control program must receive high priority. The types of examinations needed are outlined below:

Biological examination should include microscopic tests for protozoan cysts and eggs of parasites. The usual examinations should be made for bacteria. Virus testing, which is both time consuming and expensive, will need to be put on a more routine basis if potable reuse becomes common. Good progress has been made in recent years in methodology for sampling and testing viruses. Bioassays have a large role in assessing possible toxicants in effluents.

Chemical testing can be tailored to the quality requirements and the reuse application. Almost any reuse would require measurement of pH, suspended solids, chemical oxygen demand, total organic carbon, total dissolved solids, alkalinity, turbidity, ammonia, nitrates, phosphorus, and any suspected toxic chemicals such as heavy metals. Direct measurement of pesticides and trace organic residues is both important and possible with modern instruments.

TREATMENT TECHNOLOGY

In the past 15 years, significant advances have been made in wastewater treatment technology. The organic content of wastewater can be reduced to very low concentrations through the application of chemicals, use of filters, and activated carbon. Membrane treatment offers still another separation technique. Phosphorus and nitrogen removal technology is good. Bacterial and virus removal capabilities of treatment processes are high. However, some portion of the contamination remains after the best treatment. To finally remove all contaminants may require excessive processing and accompanying costs. Before programming large amounts of money and effort, the technologists need to know what residue limits are acceptable. Some specific goals in treatment technology are:

1. Continue the development and refinement of treatment technology to prepare water of any quality.

2. Collect performance, reliability, and cost data for alternative treatment systems.

SOCIO-ECONOMIC RESEARCH

It is the public who eventually pays the costs of water, and they are rightfully included in the decision making process. The full facts about reuse need to be made known and the reliability of technology fully explored and explained. Public attitudes must be sought on reusing water for potable purposes. Accurate assessment of the alternatives and costs of water will determine where and when reuse occurs.

RESPONSIBILITIES TO PROMOTE REUSE

Water reuse, if we are to achieve the maximum benefits, has to be planned on a broad basis. How might the responsibilities for optimum reuse be distributed? The Federal role has been outlined earlier in this paper. Let us consider the role of the local agency and industry.

Local Agencies Role in Water Reuse

1. Promote to the extent possible, consistent with water quality considerations, the renovation and reuse of wastewaters.

2. The water reuse potential on an area-wide basis should be determined. Specific studies on reuse in subareas would follow. Examples of objectives include the following:

a. Determine a ranked order of water uses in the local area in accordance with the acceptability of different levels of water quality.

b. Demonstrate how water reclamation can supplement available water supply.

c. Demonstrate how wastewater reclamation can relieve downstream collection and treatment systems.

d. Develop legislative, economic and planning procedures to implement water reuse.

e. Examine all available technology for reuse, assess public acceptance, aesthetics, and cost-benefit ratios.

Industrial Role in Water Reuse

1. Examine all plant practices to obtain optimum water use and recycle with a minimum of waste effluents. Try to become a minimum discharge industry.

2. Consider the use of available waters of secondary quality (sewage plant effluents, brackish waters, sea water, etc.) for suitable plant purposes.

3. Examine chemicals and processes contributing to pollution and determine if changes in either will help abate pollution.

4. Consider product recovery from waste materials.

5. Be aware of the new developments in processes to control pollution.

6. Make all plant personnel water and pollution conscious.

TIME TABLE

The United States is in the fortunate position of not needing to immediately turn to wastewaters as a direct source for preparing potable waters. Other countries such as South Africa and Israel have more urgent needs, and we shall learn from them. We all know of the long time needed to bring research results into practical full-scale use. Our time to develop and prove full-scale reuse is short. Our needs for reuse will be much greater in 10 years, and in 20 years, it will be a necessity in many parts of the United States and around the world. We hope this Workshop will be the starting point toward an integrated national effort that will bring about orderly, safe development of wastewater reuse.

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CURRENT MUNICIPAL WASTEWATER REUSE PRACTICES

C. J. SCHMIDT
President, SCS Engineers
4014 Long Beach Boulevard
Long Beach, California 90807

ABSTRACT

Reuse of municipal wastewater for irrigation, industrial, recreational, groundwater recharge, and non-potable domestic purposes is currently being practiced at over 365 locations in the United States. Much can be learned from the practices and experiences at these existing locations and new reuse projects should thoroughly investigate existing projects practicing similar reuse applications. Overall, the reuse potential in this country has hardly been touched. By contrast Israel is reported to reuse over 80 percent of its domestic sewage effluent. The greatest reuse potential is expanded use for irrigation (e.g., out of over 6,000 golf courses in the U.S., only 40 are irrigated with municipal effluent), and greatly expanded use by industry especially for cooling (there are only 11 examples of industrial reuse in the whole nation). In the semi-arid states recreational reuse and groundwater recharge has excellent economic potential. In our opinion, the *non-potable* uses for municipal effluent are a far more productive area for *our nation's* reuse efforts than is potable reuse. We must guard against overemphasizing the glamorous controversies of potable reuse at the expense of ignoring proven reuse possibilities existing all around us.

INTRODUCTION

From 1972 to 1974 SCS Engineers conducted several studies for EPA of current municipal wastewater reuse practices. The primary purpose of these studies was to make a state-of-the-art survey which would bring together information about existing reuse operations in a concise form. This information can be used by design engineers in the design of new reuse systems and by governmental decision makers in planning whether such systems are appropriate to their situations. It is also a useful tool for responsible management and technical personnel in locating existing reuse operations which can provide valuable background experience. A second purpose was to spotlight deficiencies in the available reuse information and to suggest future research to overcome these deficiencies.

SCOPE

The project compiled an updated listing of municipal wastewater reuse operations existing in 1972 and utilized questionnaires and field visits to obtain information describing current treatment and reuse practices.

The study was limited to reuse of wastewater from municipal plants with emphasis upon direct reuse of the water as it leaves the treatment plant. Projects involving indirect reuse by downstream withdrawal of surface waters containing wastewater, and industrial reuse of in-plant water were not included.

The types of reuse covered in this study are:

- Irrigation and other agricultural uses
- Cooling water
- Industrial process water
- Boiler feed water
- Recreational lakes
- Fish propagation
- Non-potable domestic use
- Groundwater recharge

A total of 367 United States and 55 foreign reuse sites were tentatively identified. Of the 367 U.S. sites, 205 were judged to be very small irrigation disposal operations. A detailed 11 page questionnaire was sent to the 162 other American sites and 55 foreign sites. The U.S. respondents totaled an excellent 154 out of the 162 questionnaires sent out. Foreign response was poor -- totaling only 6 out of 55 questionnaires sent.

EXTENT OF REUSE

As shown in Table 1, by far the greatest number of plants practice reuse by irrigation. In terms of volume, however, irrigation reuse accounts for only slightly more than half the reuse reported with industrial reuse a close second. Table 2 shows the comparative volumes by types of reuse. One large industrial reuser, the Bethlehem Steel Corporation, in Baltimore, Maryland, significantly affects the volume comparison because it utilizes 170 mgd (643,450 cu m/day) for once-through cooling.

Geographically, the reuse operations are concentrated in the semi-arid southwestern United States. As shown in Table 1, Texas with 149 municipal reuse operations and California with 145 are far ahead of other states.

Among foreign countries, Israel is a leader in municipal wastewater reuse. Roughly 86 percent of the country's total treated wastewater volume was reused in 1972 -- 62 percent for irrigation and 24 percent for groundwater recharge.

IRRIGATION REUSE

The survey showed a surprising variability in the types of crops being irrigated with municipal wastewater. Successful irrigation of 39 different crops was reported, ranging from turf (grass) for recreation (i.e., golf courses, parks, etc.) at 40 locations, down to sugar beets at 3 locations. Other crops included truck vegetables, tree fruits, and all types of grains.

Table 3 indicates the level of municipal treatment given various categories of crops. Approximately three-fourths of the plants provide the equivalent of secondary treatment. Interestingly, virtually all categories of crops are also irrigated by primary treatment effluent at some locations.

A wide range of effluent quality is being applied to crops of various locations (e.g., BOD of 15 to 370 mg/l for cotton),showing that the effluent quality ranges from poor primary to excellent secondary. Of particular interest are the high average TDS (over 800 mg/l) and Na (over 300 mg/l) levels of reclaimed waters used for irrigation. These average values indicate that relatively poor waters in terms of dissolved salts are being successfully used on a wide variety of crops. Table 4 shows survey results. When one compares the water quality values with recommended quality ranges for crop irrigation, it can be seen that "violations" of the recommended ranges are commonplace. Proper irrigation management is the key. Consideration must be given to the interrelationships between soil type, crop tolerance, drainage, water application rate, climate, and other factors.

The prevalent relationship between the municipal suppliers of effluent and the users of the effluent for irrigation is to suit the crop to the quality of the effluent. If contaminants are present which are not readily removed by conven-

TABLE 1. GEOGRAPHICAL DISTRIBUTION OF REPORTED MUNICIPAL REUSE

	Number of municipalities practicing reuse					
State	Irr.	Ind.	Rec.	Rech.	Dom.	Total
Texas	144	5	0	0	0	149
California	134	1	3	7	0	145
Arizona	28	2	0	1	1	32
New Mexico	10	0	0	0	0	10
Colorado	5	1	1	0	0	7
Nevada	4	2	0	0	0	6
Other	13	3	1	1	0	18
Total	338	14	5	9	1	367

TABLE 2. REPORTED REUSE VOLUMES BY TYPE OF REUSE

Type of Reuse	1971 Volume bil gal*
Irrigation	77
Industrial	53.5
Groundwater Recharge	12**
Recreational	1.5
Domestic (Non-Potable)	.01

*1 gal = 3.785 l.
**Expected to double in 1976 with addition of Orange County, California; Phoenix, Arizona; Oceanside, California; and Palo Alto, California, projects.

TABLE 3. MUNICIPAL TREATMENT PROVIDED FOR IRRIGATION REUSE ON SPECIFIC CROPS

		Treatment level (% of plants)		
Crop	Number of treatment plants*	Primary	Secondary	Tertiary
Grain	17	23	77	0
Corn	11	36	64	0
Vegetables	6	14	86	0
Fruit	12	18	82	0
Cotton	26	29	71	0
Fodder	51	24	73	3
Pasture	34	20	71	9
Turf and Landscape	47	9	70	21

*Certain plants supply water to more than one crop.

TABLE 4. QUALITY OF EFFLUENT APPLIED TO CROPS

		BOD (mg/l)			SS (mg/l)			TDS (mg/l)		
Crop	No. plants irrigating*	Low	High	Avg	Low	High	Avg	Low	High	Avg
Grain	17	10	1100	180	10	173	71	324	1400	837
Corn	11	10	370	76	10	135	69	8	1114	601
Vegetables	6	6	1100	193	6	127	31	5	1114	700
Fruit	12	10	160	32	9	135	58	14	1400	798
Cotton	26	15	370	84	12	259	94	324	2250	854
Fodder	51	1	370	54	0	259	66	8	1450	641
Pasture	34	7	370	50	2	118	40	6	2250	839
Turf & Landscape	47	1	80	19	0	200	26	43	2000	658

*Certain plants supply water to more than one crop

tional treatment, e.g., TDS and Boron, crops are selected which tolerate the contaminant.

Few of the reuse applications are irrigation of crops for human consumption. Most of the crops for human consumption are those that do not come into direct contact with effluent such as grapes, citrus, and other tree crops. Truck crops such as asparagus, beans, cucumbers, onions, spinach, and tomatoes are irrigated at least partially with effluent only at three California sites -- Camarillo, Irvine, and Livermore; and at two Washington sites -- Walla Walla and Warden.

Table 5 shows the prevalence of effluent storage prior to irrigation. Only 18 of the irrigation reuse operations reported no effluent storage available, and most have storage of two days or more. Comments received from operators, irrigators, and regulatory agencies emphasized the importance of substantial storage facilities for effluent and tailwater in order to balance irrigation demands, allow for rainy periods when the fields are saturated, and prevent run-off.

Effluent transport distances to potential reuse sites is an important economic factor. Table 5 also displays the ranges of irrigation water transport distances reported by current agricultural reusers. The figure illustrates that 20 percent of all irrigation reusers are directly adjacent to the municipal treatment site and less than 6 percent are more than 4 miles away. The data received indicates that the bulk of the reusers lie two miles or less from their supplier.

Only 25 municipal producers of irrigation water report they sell their renovated product. Most municipalities look upon the irrigation operations as primarily a means of disposal and are not prone to demanding payment for effluent which they would otherwise waste. In some cases, the irrigation operation allows the municipality to provide

TABLE 5. STORAGE CAPACITY OF IRRIGATION WATER SUPPLY FACILITIES AND DISTANCE FROM TREATMENT PLANT TO IRRIGATION REUSE LOCATION

Available storage time days	Number of plants	Transport dist. from treatment plt. to irri. reuse-miles*	Number of plants
0	17	0	25
0.5-1	2	0-0.25	7
1-2	7	.25-.5	22
2-10	26	.5-1	14
10-20	7	1-2	18
20-30	9	2-4	14
over 30	16	over 4	7

*1 mile = 1.61 km.

only primary treatment, whereas if discharge were made to surface waters, a high degree of secondary treatment would be necessary. Municipal revenues from irrigation are estimated to equal less than 1 percent of the treatment cost incurred by the municipalities charging for their effluent.

Among those municipalities charging for their effluent, it appears that charges for effluent are primarily influenced by factors other than effluent quality. Among these factors are fresh water cost and availability in the area, prior water rights in the area, and the municipality's failure to recognize its effluent as a valuable commodity rather than something to be discarded.

INDUSTRIAL REUSE

Responses to this survey indicated that reuse of municipal wastewater effluents by industry amounted to 53.5 bil gal (202.5 bil l) in 1971, or 40 percent of the total United States reuse volume. The bulk of the industrial reuse volume is due to one user, the Bethlehem Steel Plant in Baltimore, Maryland, which utilizes 44 bil gal (166.5 bil l) annually for once-through cooling.

Only 14 industrial plants were found to be reusing municipal wastewater in the United States. These 14 facilities include 3 city-owned power plants, so private industry is represented by only 11 plants in the entire nation. Obviously, numerous potential reuse opportunities remain unrecognized.

Water quality requirements vary widely between industries, between different plants in the same industry, and between various processes within a single plant. The bulk of industrial water is used for cooling, boiler feed, washing, transport of materials, and as an ingredient in the product itself. As shown in Table 6, cooling is predominant in the reuse of municipal wastewater, accounting for approximately 154 mgd (582,890 cu m/day) out of the total 156 mgd (590,460 cu m/day) reported industry reuse.

Table 7 shows the major industry classifications using municipal wastewater. Power generation leads the list with 6 plants followed by petro-chemical with 5.

TABLE 6. TYPE OF INDUSTRIAL REUSE IN THE UNITED STATES

Type of use	Number of plants (1)	Percent of totals	Reuse volume (mgd) (2)
Boiler feed	3	17	1
Process	3	17	1
Cooling	12	66	154

(1) Some plants use municipal effluent for more than one use.
(2) One mgd = 3,785 cu m/day

TABLE 7. MAJOR INDUSTRY CLASSIFICATIONS USING MUNICIPAL WASTEWATER

Industry	Number of plants	Percent of total volume reused
Basic Metal Manufacturers	1	74
Power Generation	6	20
Petro-Chemical	5	5
Mining and Ore Processing	2	1

Cooling Water

Eleven of the fourteen industrial reusers report cooling water as the primary use for the reclaimed municipal sewage. Cooling water technology is complex, and the use of reclaimed sewage presents special problems of treatment and control to responsible operating personnel. The differences between treated sewage effluent and fresh water must be recognized and planned for, or serious problems may occur in the heat exchange and cooling system.

Table 8 shows practice at specific locations in gearing cooling water make-up treatment methods to the quality of the municipal effluent being used. The table indicates that superior quality sewage effluents, e.g., the city of Burbank, California, can be used successfully with only an increase in chlorine, acid, and corrosion inhibitors required to put the effluent on almost equal status with fresh water. If, however, the treated sewage effluent is of average quality or worse, then lime clarification treatment is necessary to remove suspended solids and organics prior to use.

Boiler Feedwater Make-Up

Three industrial plants in Texas report the use of sewage effluent for makeup to boilers. Each of the users provides substantial additional treatment, the extent of which is dependent upon the type of boiler for which the makeup water is intended. Low pressure boilers successfully utilize effluents which have been clarified, softened, and reduced in phosphates. High-pressure boilers require makeup water which has been given the additional treatment steps of dissolved solids removal or deionization.

Industrial Process Water

Three plants reported using reclaimed sewage effluents for processing purposes. All are in the mining and steel making industries. These are:

Bagdad Copper Corporation
Bagdad, Arizona

Phelps Dodge Corporation
Morenci, Arizona

Bethlehem Steel Corporation
Baltimore, Maryland

The two Arizona plants utilize the sewage effluent in the mining of copper. Bethlehem Steel Corporation uses the bulk of its 170 mgd (643,450 cu m/day) inflow of treated sewage effluent for cooling purposes, but small amounts are also used for a variety of processing within this fully integrated iron and steel plant.

Transport and Storage

Transport distances are often an important consideration in the feasibility of wastewater reclama-

TABLE 8

EFFLUENT QUALITY VERSUS USER TREATMENT REQUIRED FOR COOLING TOWER MAKE-UP WATER

	Effluent quality mg/l			
Selected Users	BOD	SS	TDS	User treatment processes
City of Burbank, CA	2	2	500	Shock chlorination, pH adjustment, corrosion inhibitor
Nevada Power Co. Las Vegas, NV	20	20	1,000-1,500	Shock chlorination, lime clarification, pH adjustment, corrosion inhibitor
Southwestern Public Service Company Amarillo, TX	10	15	1,400	Lime clarification, ph adjustment, shock chlorination, corrosion inhibitor
City of Denton, TX	30	30	130	Shock chlorination, ph adjustment, corrosion inhibitor (Treatment insufficient for effluent of this quality)
El Paso Products Company Odessa, TX	10	13	1,300	Lime clarification, pH adjustment, filtration, softening.

tion. Table 9 shows the distances of various industrial users from the municipal suppliers. In all reported cases, the user has been responsible for financing the effluent transport facilities.

Storage facilities for the reclaimed effluent were constructed by eight of the industrial reusers. Table 9 illustrates the range of storage facility sizes.

TABLE 9. STORAGE CAPACITY OF INDUSTRIAL WATER SUPPLY FACILITIES AND DISTANCE FROM TREATMENT PLANT TO INDUSTRIAL REUSE LOCATION

Available storage time days	Number of plants	Transport distance from treatment plants to irrigation reuse - miles*	Number of plants
0	5	0 - .5	1
.5-1	1	.5 - 1	3
1-5	5	1 - 2	4
over 5	2	2 - 4	3
		4 - 6	1
		over 6	1

*1 mile = 1.61 km

Industrial Reuse Economics

Economics is the prime motivating force of industry, and the use of reclaimed wastewater is governed by the cost of alternate water supply procurement and treatment. In locations where public water supplies of good quality and quantity are available at low cost, treatment and reuse of renovated water by industry has not been economically attractive. Thus, it is not surprising that most industrial users of treated municipal effluent are in the semi-arid southwestern states where water costs are relatively high and water quality tends to be poorer in terms of TDS and hardness.

Several of the industrial plants do not have an adequate alternate source of water and are strongly dependent upon their sewage effluent supply. Most of the other plants, however, have chosen to use reclaimed water because it is more economical than use of fresh water.

The cost of reclaimed water may be divided into two parts. First, the cost of procuring the reclaimed water, including payments to the municipality, construction of effluent transportation facilities, and all other costs required to deliver the effluent to the industrial plant site. Second, the cost of treating the reclaimed water to make its quality suitable for the intended use.

When comparing reclaimed water to fresh water, the cost of procuring reclaimed water is virtually always less; however, the cost of treatment is usually more. Disregarding Colorado Springs, which is a pilot operation, the range in purchase price of municipal effluent to industrial users is nothing to \$144/mil gal (\$38,100/mil cu m) with a median of \$79/mil gal (\$20,800/mil cu m).

Additional treatment costs generally comprise the largest portion of the cost of reclaimed water to industry. The treatment costs depend upon the end use quality required, the quality of the sewage effluent, the degree of treatment required, the quantity of water treated, and other factors. For cooling water use in recirculating systems, the reported industry treatment costs varied from \$100/mil gal (\$26,400/mil cu m) to \$550/mil gal (\$145,500/mil cu m). As shown in Table 10, the lower cost is for treatment of exceptionally high-quality effluent produced at Burbank, California, and the higher cost is for a very sophisticated reclaimed water treatment system at Odessa, Texas.

For boiler feed makeup water use, Cosden Oil and Chemical Company reported treatment costs of \$742/mil gal (\$196,000/mil cu m). Treatment costs incurred at other plants treating a portion of the effluent for boiler feed makeup water are estimated by SCS Engineers to be in the range of \$500/mil gal (\$132,000/mil cu m) to \$1,000/mil gal (\$264,000/mil cu m), as shown in Table 10.

The revenue received by the municipalities from industrial reusers is less than the cost of treatment to the municipality. However, in all cases, the municipality would have had to provide equivalent treatment prior to discharge in any case, so any revenues for sales of effluent are a bonus to the local municipal taxpayer.

RECREATIONAL LAKE REUSE

There are three major recreational lake reuse projects in the United States; i.e., Santee, Tahoe, and Lancaster, California. Each of these recreational lake projects has provided important background for advances in wastewater treatment.

The Santee County Water District Lakes project is justifiably famous for its pioneering work. Since 1961, the Santee Lakes have been used progressively for recreational activities involving increased human contact as laboratory results and epidemiological

TABLE 10

INDUSTRIAL USER
COSTS FOR RECLAIMED WASTE

User	Cost to Procedure Effluent ($/mil gal)*	User Treatment Cost ($/mil gal)*	Total Effluent Cost ($/mil gal)*
Bagdad Copper Corp. Bagdad, Arizona (Process)	0	0	0
Phelps Dodge Corp. Morenci, Arizona (Process)	0	0	0
City of Burbank California (Cooling)	43	100	143
City of Colorado Springs Colorado (Cooling)	320	---	---
Bethlehem Steel Corp. Baltimore, Maryland (Cooling, Process)	1.33 (avg)	N/A	N/A
Dow Chemical Co. (Cooling) Midland, Michigan	3.33 (avg)	N/A	N/A
Nevada Power Co. (Cooling) Las Vegas, Nevada	25	193	225
Champlin Refinery (Cooling) Enid, Oklahoma	7	N/A	N/A
Southwestern Public (Cooling) Service Co. Amarillo, Texas	80	160	240
Cosden Oil & Chemical Co. Big Spring, Texas (Boiler Feed)	79 (avg)	742	821
City of Denton (Cooling) Texas	80	100	180
Southwestern Public Service Co., Lubbock, TX (Cooling & Boiler Feed)	144	160	304
El Paso Products Co. Odessa, Texas (Cooling & Boiler Feed)	125	550	675
Texaco, Inc. (Cooling) Amarillo, Texas	90	194	284

* /mil gal = 0.003785/mil cu m

information indicated that such activities could be conducted without health hazard. The lakes are now used for boating and fishing with associated activities along the shoreline but are not open for whole-body, water-contact sports. In 1965, an area adjacent to one of the lakes was equipped with a separate flow-through swimming basin which used reclaimed water that was given additional treatment by coagulation, filtration, and chlorination.

The best documented tertiary treatment process in the nation is found at Lake Tahoe, California, where five tertiary treatment steps are combined to provide exceptionally high-quality effluent. Activated sludge effluent is subjected to chemical treatment for phosphate removal, nitrogen removal, filtration, carbon adsorption, and chlorination. This plant also utilizes advanced sludge handling techniques, lime recalcination, and carbon reactivation. The treated effluent is pumped 14 miles (22.5 km) through a lift of 1,460 ft (446 m) and then flows through gravity pipeline an additional 13 miles (20.9 km) to Indian Creek Reservoir. Indian Creek Reservoir has a capacity of 3,200 acre-ft (3,947,200 cu m). It is approved for body-contact sports (swimming) and is reported to boast excellent trout fishing.

An interesting new project is located at Lancaster, California, where, since 1971, the Sanitation Districts of Los Angeles County have sold renovated wastewater to the County of Los Angeles for use in a chain of three recreational lakes. The lakes have a capacity of 80 mil gal (302.8 l) and serve as a focal point for the County's 56-acre (22.7 ha) Apollo Park. The park, located near Lancaster, California, was opened to the public in 1973 and features fishing, boating, and picnic areas. Treatment of Lancaster consists of a series of eight oxidation ponds followed by flocculation and sedimentation for removal of phosphates, suspended solids and algae, filtration to polish the effluent, and chlorination.

Each of the three recreational projects briefly described above is unique but they share much in common. All have found it technically feasible to consistently produce effluent meeting drinking water coliform standards. All practice phosphate removal for algae control and filter the effluent to reduce turbidity. Many species of fish have been grown successfully, including trout.

DOMESTIC REUSE

Great controversy surrounds the subject of domestic reuse of wastewater for potable purposes. Much less opposition is voiced to non-potable domestic reuse; e.g., toilet flushing. It is not within the scope of this paper to enter into the controversy.

The only current example of direct reuse for domestic purposes in the United States is the non-potable domestic reuse program managed by the National Park Services at Grand Canyon National Park. The Grand Canyon domestic reuse operation provides an average of 30,000 gpd (113.6 cu m/day) through a separate distribution system for toilet flushing, car washing, irrigation, construction, and car watering. Major tertiary treatment given the activated sludge effluent is anthracite filtration and heavy chlorination. Cost to the user for the reclaimed water is \$1,000 per mil gal (\$264,000/mil cu m) to \$1,750 per mil gal (\$463,000/mil cu m). This premium price can be obtained because fresh water sells for \$2,450 per mil gal (\$684,000/mil cu m) in the area.

GROUNDWATER RECHARGE

Groundwater recharge by percolation or well injection is being practiced at six sites in the U.S. with three more about to begin. Table 11 summarizes the operations.

TABLE 11

INVENTORY OF RECHARGE OPERATIONS

Location	Managing agency	Purpose of recharge	MGD
Camp Pendleton, CA	U.S. Marine Corp.	. Groundwater replenishment . Salt water barrier	4
Hemet, CA	Eastern Municipal Water District	. Groundwater replenishment	2
Long Island, NY	Nassau County Department of Public Works - U.S. Geological Survey	. Groundwater replenishment . Salt water barrier	0.5
Oceanside, CA	Water and Sewer Dept.	. Treatment for reuse	6(3)
Orange County, CA	Orange County Water District	. Groundwater replenishment . Salt water barrier	15(1)
Palo Alto, CA	Santa Clara Valley Water District	. Salt water barrier . Treatment for reuse	2(2)
Phoenix, AZ	U.S. Water Conservation Laboratory	. Treatment for reuse	15(1)
San Clemente, CA	City of San Clemente	. Salt water barrier	2
Whittier, CA	L.A. County Flood Control District	. Groundwater replenishment	25

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(1) Operational 1975.
(2) Operational 1976.
(3) Present system temporarily provides 1 MGD for groundwater replenishment. New 6 MGD program operational 1975.

As groundwater supplies continue to be overdrafted, the problems of salt water intrusions and depleted supplies will cause authorities to look toward wastewater reuse with groundwater recharge, as a viable, expedient, and financially feasible alternative. Groundwater recharge with treated effluent has been shown to be an effective method of repelling salt water intrusion and in providing exceptional tertiary treatment for reuse. The use of effluent for these purposes should increase greatly in coastal areas threatened by intrusion and in the arid southwestern U.S.

Recharge by percolation has several advantages over recharge by well injection: standard quality secondary effluent can be used successfully, capital costs and operation and maintenance requirements are minimal, and the soil provides exceptional tertiary treatment under proper operating conditions. Recharge by percolation is most successful when: SS concentration in effluent is low (<20 mg/l); infiltration rates are high (>2 ft/day); and operation follows a cyclic flooding-draining-drying schedule to reduce surface clogging. Where percolation is not feasible (i.e., land not available, infiltration rates too low, etc.), well injection of effluent promises to be effective in repelling salt water intrusion and replenishing groundwater basins. The Palo Alto, Orange County, and Long Island programs are all in various stages of design and construction. Successful well injection recharge requires high quality tertiary effluent (e.g., BOD < 5, SS < 1, $PO_4 < 1$, FE < 0.5, JTU < 0.3 units) usually achieved with chemical coagulation/settling, ammonia stripping or nitrification-denitrification, filtration, and carbon adsorption. Full scale recharge by well injection should be preceded by extensive pilot studies to determine the hydraulic characteristics of the receiving aquifer. This is necessary to quantify the flow volume the aquifer can handle, the directions and velocities of underground flow, and the quality of effluent necessary to prevent clogging. Although well injection recharge is very expensive, involving extensive tertiary treatment and a deep well network, it is still economically attractive if it successfully repels salt water intrusion and/or supplements domestic supplies to eliminate or delay the need to develop costly alternate fresh water sources.

Both percolation and injection recharge systems can be operated in conjunction with extraction facilities to ensure that none of the effluent mixes with native groundwater. The high quality extracted water having received further treatment by migration through the soil can be reused for irrigation, recreation, or industrial purposes.

RECLAIMED WASTEWATER MARKET CONSIDERATIONS

Obviously, a municipal wastewater reuse program must have customers for its reclaimed water to be successful. It appears from the results of this study that generally municipalities have not sought out potential reusers, particularly among private industry. Rare is the municipality which thinks of its effluent as a commodity to sell rather than a nuisance to waste. Yet, reused water has enormous potential for increasing the water resources of individual localities and the nation. If reclaimed wastewater is used to satisfy demands for non-domestic uses of water wherever feasible, the fresh water thus saved will be able to satisfy much of the future increase in demand for general water supply.

One of the first places for a municipality to look is at its own municipal activities. Municipal power generation stations, golf courses, parks, school grounds, farms, and recreational lakes are all successfully using their own treated municipal effluent as a water supply. Other governmental agencies, e.g., county, state, and federal, are also excellent prospects to purchase reclaimed water.

Private irrigation reuse sales opportunities are prevalent in most areas. Private farms, orchards, and golf courses are all amply represented among existing reusers. Most of the existing irrigation reuse operations are located very near the treatment plant. It appears that more emphasis might be given to selling effluent to large irrigators remote from the treatment plant.

There are only eleven private industrial reusers of municipal effluent in the nation, and two of these are "company towns" for large copper mines. Undoubtedly, many opportunities for industrial reuse of municipal wastewater are being ignored, especially for cooling purposes. As the results of this study amply demonstrate, municipal effluent can be successfully used for both once-through and recirculating cooling systems. There is extra cost to the industry in treatment and chemicals in the use of reclaimed water instead of fresh water; however, in many cases, this extra cost is offset by the lower cost of the used water. The potential market is staggering. The power industry alone uses over 75 bil gal per day (283.9 bil l/day) of cooling water.

Only a small percentage of municipal wastewater is presently reused in this country. To conserve our national fresh water resources, government and the public will be wise to strongly support the expanded practice and continued development of municipal wastewater reclamation.

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DISCUSSION

QUESTION: Mr. Henry J. Ongerth, California Department of Health, Berkeley, California. You have identified park and golf course irrigation as irrigation rather than as recreation.

RESPONSE: Mr. Schmidt. Yes, absolutely. Thanks. That's a good question. Recreation was only recreational lakes.

COMMENT: Mr. Robert B. Dean, Advanced Waste Treatment, US-EPA, Cincinnati, Ohio. There is a perfectly deliberate bias in your whole survey in that you don't include water that has been discharged to a stream. I understand that this was necessary, but the conclusion is biased because there are many places in the arid Southwest where the water goes into a stream which is dry and it disappears into the groundwater. This is unprogrammed groundwater recharge; it is nevertheless groundwater recharge.

In California, at Dublin, they were putting extremely tight standards on their water because they knew it was all running into the dry wash and would turn up in the Niles aqueduct. There's a lot of that. So there is a lot more reuse than you give us credit for.

RESPONSE: Mr. Schmidt. Thank you. That's a very good point and very true.

COMMENT: Mr. John N. English, EPA, Cincinnati, Ohio. I think that groundwater recharge is potable reuse in that Henry Ongerth with the State Health Department of California is quite concerned about the organics, and so forth, that are getting into the groundwater.

RESPONSE: Mr. Schmidt. That's also a very good point, John.

COMMENT: Mr. John N. English, EPA, Cincinnati, Ohio. Groundwater recharge is potable reuse. It may not be direct potable reuse, but it's still potable reuse. It is practiced in California and in other areas. The state health people are concerned, and that's one of the reasons that we've got to talk about potable reuse and its associated health effects and treatment technology.

I think that industrial use and agricultural use are less expensive, and where they will reduce water consumption and are the best alternatives for that area, then I think we ought to practice such uses. However, I think potable reuse, whether it is indirect, such as groundwater recharge, or direct, is also important and is also a viable area of concern. In fact, it is an area about which the people of California and Denver are very concerned. They may not have the cheaper alternative of agriculture or industrial use.

You and Frank Middleton identified the various uses and indicated the desirability of using the water where it is most economical, but there is a tremendous need for information on potable reuse and anything related to health effects.

RESPONSE: Mr. Schmidt. I agree completely, John. In essence, the point I was trying to get across is that I don't think we should lose sight of all the less controversial reuse potentials while we are pursuing the potable concept.

QUESTION: Mr. Lawrence Gallowin, National Bureau of Standards, Washington, D.C. Did you discover any information relative to nutrient values in agricultural reuse and the possible impact on fertilizer requirements?

RESPONSE: Mr. Schmidt. Yes. As might be expected, the municipal effluent does provide fertilizer constituents to the crops, and in a few cases where crops were irrigated with both municipal effluent and fresh water on a more or less side-by-side basis, in every case the crops irrigated with municipal effluent did better.

COMMENT: Mr. Denny S. Parker, Brown & Caldwell, Walnut Creek, California. From one of your statements about the treatment provided for cooling water, one might infer that the only reason the lime treatment was provided was for clarification. Actually, lime treatment, in addition to providing that clarification, also removes phosphorus which can form a scale on heat exchange surfaces. This is probably the most universal reason for using lime treatment in the cooling water sequence.

RESPONSE: Mr. Schmidt. You are absolutely right.

WASTEWATER REUSE IN ORANGE COUNTY, CALIFORNIA

Neil M. Cline, Secretary Manager
Orange County Water District
and
David G. Argo, Assistant District Engineer
Orange County Water District

INTRODUCTION

In 1934 the Board of Directors of the Orange County Water District in Orange County, California adopted a resolution that the Board "go on record as favoring the reclaiming of all sewerage of Orange County cities which is now going to the ocean."

The Board had been in existence for only one and a half years, and was wrestling with the problem of attempting to find some supplemental water to replenish the overdrafted groundwater basin. Water levels in the County were dropping rapidly; the upstream communities in the Santa Ana River, the only significant replenishment source, were diverting water in increasing quantities; and seawater was encroaching on groundwater supplies of the coastal communities.

The usual eloquent argument was made--that it was absurd to use water once and dump this precious resource to the sea. But the sum total of the resolution made by our District forty-one years ago was a cursory review of the state of the art of salvaging wastewater, and it was determined there were just too many unknowns to set a direct course on reuse, and that alternatives would have to be developed, with research conducted before reclamation would be feasible.

Fortunately for Orange County, it started raining in 1936 in unprecedented quantities, and the water shortage problems were overshadowed by floods and fear from floods. In the meantime, The Metropolitan Water District of Southern California completed its Colorado River aqueduct and alternate sources of water were available for local use. However, in the period following World War II Orange County was rapidly urbanized, the groundwater heavily overdrafted, and seawater intruded inland 3-1/2 miles. To control further seawater intrusion, groundwater replenishment was instigated, and since 1949 the District has placed over 2,000,000 acre-feet of surplus Colorado River water in the basin through surface spreading.

At the present time water supply in the District is from the groundwater basin through wells or by direct service from The Metropolitan Water District of Southern California. In 1974 the demand for water in the District exceeded 300,000 acre-feet, of which over 200,000 were supplied from the basin and the balance by direct service by MWD.

To further reduce intrusion and develop greater flexibility in groundwater utilization, in 1963 the Orange County Water District began studies to develop an effective hydraulic barrier. It was concluded that as much as 30,000 acre-feet per year could be required to operate an efficient barrier and provide supplemental groundwater supplies to the rapidly developing coastal cities within the District. The burning question was, where would the District obtain 30,000 acre-feet of noninterruptible source. The Colorado River water supply was being severely challenged by Arizona, the Northern California water supplies were a dream, and so once again the Board turned to wastewater. Since 1963 the District, in cooperation with the then Federal Water Pollution Control Administration, California State Department of

Health, and the Orange County Health Department, has been working to develop and apply wastewater for barrier and water supply purposes.

Following years of intense study, including model and pilot plant operations, in 1971 the District began construction of Water Factory 21. This advanced wastewater treatment plant will reclaim up to 15 mgd of secondary municipal treatment effluent for blending with other waters and injection, to form a barrier to seawater intrusion. At present, intermingling of the injected water with potable groundwater supply is being questioned by regulatory authorities due to various unknowns which pose hazards to public health. The questions are primarily concerned with continuous reliability of plant operation, ability of the processes to eliminate human pathogens, and potential health effects from organic materials remaining in the reclaimed water. These questions are of national interest and must be answered before reclamation of wastewaters for human consumption becomes a viable alternative to water resources development. There are several water-short areas in the United States where pressures for water reclamation are great.

The goal of the Orange County Water District as well as the cooperative and regulatory agencies at County, State and Federal levels, must be to establish confidence in reusing wastewater for potable purposes.

Sadly, in Orange County we are not in a position today, as we were forty years ago, to rely on rainfall to rescue us from a prolonged drought. With the urbanization of both upstream and local areas, the runoff pattern has radically changed and we can no longer rely on substantial replenishment through local storms. We are committed to total water management, which must include an increasing dependency upon imported supplemental water and wastewater reuse.

To accomplish this goal, research studies must be undertaken to gather significant data in several areas of concern:

1. Demonstration of reliable and fail-safe wastewater treatment technology to enable control of effluent variability and the continuous production of potable quality water.
2. The identification, measurement, and monitoring of trace materials (chemical, physical, and biological) and residues in the effluent from wastewater treatment systems producing potable quality water.
3. Development of a more rapid virus detection methodology, mandatory to enable the water purveyor to operate with the confidence consistent with national health standards.
4. Intensive analyses of the efficiency and feasibility of disinfectant and sterilization methods, including an in-depth review of chlorination and ozonation practices.
5. A thorough study on the health effects of high TDS and low TDS waters. There are conflicting research reports that are perplexing to the water purveyors, and additional work is essential.
6. Continued and expanded research to analyze the effects of ocean discharge of sewage wastes.
7. Broadened research in sludge disposal and mineral recovery.
8. Expanded development of programs for alternate fuel sources to lessen the energy impacts of water salvage facilities.

WASTEWATER RECLAMATION AT WATER FACTORY 21

The Orange County Water District (OCWD) was formed in 1933 by special act of the California Legislature. Under this act, OCWD has the responsibility and authority to provide:

1) Management of the groundwater basin;

2) Conservation of the groundwater supplies, including both quantity and quality of the water; and

3) Protection of Orange County's water rights in the natural flows of the Santa Ana River.

The District covers an area of about 315 square miles, generally overlying the coastal basin of the Santa Ana River in Orange County. Water supply within the District is from the groundwater basin through wells or by direct service from the Metropolitan Water District of Southern California (MWD). At the present time, the total water use within the District is about 300,000 acre feet per year; two-thirds of this amount is supplied by the underground basin and the remaining one-third supplied through direct service by MWD.

The growth rate of Orange County in the transition from an agricultural to an urban economy after World War II placed large demands upon the groundwater supply. The basin was overdrafted and by 1956 there was an accumulated overdraft in excess of 500,000 acre feet. Because of this overdraft, seawater intruded inland as much as 3 1/2 miles in the Talbert Gap (the ancient channel of the Santa Ana River). In 1948, OCWD began importing Colorado River water and percolating it into the groundwater basin through surface spreading facilities in the Santa Ana River. OCWD owns approximately 750 acres of the Santa Ana River bed, and utilizes the area for ponding imported water and natural flows of the river to replenish the underground basin. In addition, the District owns two large off-river spreading basins of approximately 100 acres each. This groundwater replenishment program by surface spreading facilities has corrected the dangerous overdraft conditions and has provided an adequate groundwater supply which has sustained the County's growing economy.

Although OCWD has managed to place enough water in the basin to keep the water table at an adequate level to prevent widespread damage from seawater intrusion, saltwater has penetrated as far inland as Garfield avenue in the Talbert Gap. To prevent further intrusion in this location, and to permit greater flexibility in the management of the groundwater basin, OCWD has under construction a barrier to seawater intrusion.

The feasibility and necessity of the Orange County Coastal Barrier Project has been reviewed by several agencies and a summary report was prepared in 1967. This report was presented to the Board of Directors of the Orange County Water District at their meeting on January 18, 1967. At this same meeting, the Board adopted Resolution No. 67-4, which resolved that the Orange County Coastal Barrier Project is feasible and necessary.

The hydraulic barrier to seawater intrusion will be composed of a series of seven extraction wells (already constructed and in operation) about two miles inland from the coastline and a series of 23 injection wells about four miles inland from the coastline.

OCWD reviewed the barrier project injection water requirements and concluded that about 30 mgd (million gallons per day) of injection water will be required; there are several possible sources of supply for this injection water:

1. Imported water either from the Colorado River or State Water Project;
2. Water produced from a deep aquifer not subject to seawater intrusion;
3. Reclaimed wastewater;
4. Demineralized brackish groundwater;
5. Desalted seawater;
6. Blend of the above waters.

A blend of reclaimed wastewater and desalted seawater was selected for the injection well supply. This blend will be supplemented with deep groundwater as required. A 15 mgd wastewater reclamation facility is being constructed with funds provided by OCWD, the State of California Water Resources Control Board and the Federal Environmental Protection Agency. A 3 mgd seawater desalting facility is being constructed with funds from OCWD and the Federal Office of Saline Water.

Previous Studies

The Orange County Water District (OCWD) has conducted an extensive applied research and development program in wastewater reclamation and groundwater recharge. The program began in July 1965 and has progressed in four phases. The first phase was concerned with the feasibility of treating trickling filter effluent for injection through wells into a confined aquifer system. During this phase, a study of treatment operations was conducted in both laboratory and pilot scale units. Treatment prior to injection into one single-casing gravel packed well consisted of clarification, filtration and chlorination. The progress of the first phase was reported by Hennessy, et al, (1) and the findings of the first phase were reported in detail in a report (2) to OCWD in 1967. The first phase was primarily concerned with treatment methods, and injection was not extensively studied. The primary objectives of Phase Two were to determine the long-term fate of injected reclaimed water, and evaluate the performance of a unique multicasing injection well. During Phase Two, reclaimed water was injected through two multi-casing wells for about ten months. The travel of the injected water was monitored by nine wells located 100 to 1,000 feet from the injection wells. The progress of this second phase work was reported by Wesner and Baier, (3) and the final report was published in October 1970. (4) It was the general conclusion of these Phase Two studies that additional treatment was required prior to injection because color and odor persisted in injected water even after 1,000 feet of underground travel. In July 1969, a report was prepared that surveyed advanced treatment methods and recommended additional pilot studies. (5)

Phase Three consisted of additional pilot wastewater reclamation studies conducted from May 1970 to June 1971. During this phase, treatment in the pilot wastewater reclamation facilities consisted of: (1) chemical clarification; (2) ammonia stripping; (3) recarbonation; (4) mixed media filtration; (5) carbon adsorption; and (6) chlorination.

The purpose of Phase Three was to develop design data for the full size plant. Results of the pilot plant studies reported by Wesner and Argo (6) concluded that the above treatment scheme could produce a water suitable for groundwater recharge by injection. Table I shows typical quality for both the pilot plant influent and effluent. The source of the pilot plant's influent was trickling filter effluent from the existing secondary treatment plant of the Orange County Sanitation District.

Purpose and Scope

The purpose of this report is to summarize the District's past and present activities in wastewater reclamation. The report describes the treatment processes required to utilize reclaimed wastewater for an injection barrier supply. The report presents the design criteria for the various unit operations including outline plans, construction costs and estimated operation and maintenance costs. The report also reviews the quality requirements for the injection water established by the regulatory agencies.

WATER FACTORY 21 - WASTEWATER RECLAMATION FACILITIES

Basis of Design

Water from the reclamation plant will be injected into the groundwater basin and will eventually be withdrawn and reused for domestic, industrial and irrigation purposes. Therefore, at the point of withdrawal, the water must meet drinking water standards. OCWD's test program of treatment operations and injection has defined the quality parameters desirable for injection. Prior to injection, the reclaimed wastewater will be blended with desalted seawater and, if needed, water produced from a deep aquifer not subject to seawater intrusion.

It is necessary to reduce the concentration of dissolved organic material to a low value to eliminate taste, odor and color. Ammonia nitrogen will be removed to lower the total oxygen demand and to make the water more amenable to disinfection and phosphorous will be removed to control algae growths in the reuse system. Bacteria and virus should not be present in the injection water and the concentration of potentially toxic elements will meet the U.S. Public Health drinking water standards. Suspended

TABLE I TYPICAL WATER QUALITY, PILOT WASTEWATER RECLAMATION PLANT INFLUENT AND EFFLUENT

Constituent	CONCENTRATION (mg/l except odor and color) Influent	Effluent
Calcium	70 - 110	50 - 80
Magnesium	20 - 45	1 - 3
Sodium	240 - 260	240 - 260
Potassium	20 - 35	20 - 35
Bicarbonate	200 - 450	150 - 170
Sulfate	270 - 350	270 - 350
Chloride	300 - 350	300 - 350
Phosphate	20 - 25	< 1
Nitrogen		
Organic	5 - 15	< 1
Ammonia	15 - 30	< 2
Nitrite	< 1	< 1
Nitrate	< 1	< 1
Total Dissolved Solids	1200	1000 - 1100
Total Hardness	255 - 460	130 - 210
Suspended Solids	30 - 80	< 1
BOD	30 - 80	< 2
COD	50 - 200	10 - 30
MBAS	3 - 4	0.1
Threshold Odor No.	50 - 100	< 2
Color, Units	30 - 50	< 2
Arsenic	0.00 - 0.01	0.01
Barium	< 0.02	< 0.02
Cadmium	0.01 - 0.13	0.000 - 0.005
Chromium (hexavalent)	0.10 - 0.20	0.00 - 0.04
Copper	0.09 - 0.39	0.02 - 0.30
Iron	-	0.05 - 0.25
Lead	0.00 - 0.05	0.00 - 0.04
Manganese	-	0.05 - 0.10
Mercury	< 0.001 - 0.003	< 0.001 - 0.003
Selenium	0.00 - 0.09	0.000 - 0.003
Silver	0.00 - 0.01	0.00 - 0.01
Zinc	0.07 - 2.08	0.02 - 0.07

solids in the injection water should be as low as possible to minimize well clogging. The California State Water Resources Control Board, Santa Ana Region, and the State Department of Public Health have established requirements for the injection water. These requirements are shown in Table 2. The State Health Department also requires monitoring for viruses.

Existing Sewerage System

All but the southeasterly portion of OCWD lies within the service area of the County Sanitation Districts of Orange County. At the present time, there are seven sanitation districts which own and maintain about 400 miles of major trunk sewers with more than 20 pump stations. Jointly, the seven districts operate two treatment plants to process wastewater for ocean disposal. Treatment Plant No. 1 is located about four miles from the coast adjacent to the Santa Ana River and has a capacity of 50 mgd. This plant gives primary treatment to all of the flow, and secondary treatment by trickling filters to 15 mgd. It is this secondary treated effluent which is available to OCWD for reclamation and an injection barrier supply. The quality of the trickling filter effluent from Orange County Sanitation District's Treatment Plant No. 1 is shown in Table 3.

Water Factory 21's Plant Flow and Treatment System

The wastewater reclamation process consists of:

1. Chemical clarification for phosphorus and suspended solids removal. This process also removes some calcium, magnesium and trace metals.
2. Ammonia stripping for nitrogen removal.
3. Recarbonation for pH control and additional removal of calcium.
4. Filtration for additional suspended solids removal to produce an effluent with turbidity less than 1.0 Jackson Turbidity Unit (JTU).
5. Activated carbon adsorption for removal of soluble organics - the compounds which cause taste, odor and foam.
6. Chlorination for destruction of bacteria and virus.
7. Blending with desalted seawater.
8. Lime sludge recalcining and reuse.
9. Activated carbon regeneration and reuse.

Figure 1 is a schematic flow diagram with the treatment system divided into liquid processing and solids handling. The major design criteria for Water Factory 21's wastewater reclamation facilities are summarized in Table 4.

Chemical Clarification

The primary purpose of the chemical clarification system is to remove suspended solids and phosphorus, but this process also serves several other important functions including:

1. Removal of some potentially toxic trace elements.
2. Reduction in calcium and magnesium which contributes to water hardness. The total dissolved solids content of the water is also reduced through the removal of these elements.
3. At least partial disinfection of the water occurs due to the fact that the pH is maintained at about pH 11.0 for a period of about one and a half hours. This will produce a substantial reduction in bacteria and virus.
4. Elevation of the pH to about pH 11.0 which is necessary for efficient ammonia stripping.

There are four major components of the chemical clarification system: rapid mixing, flocculation, settling, and effluent pumping. Figure 2 shows an isometric view of the chemical clarification system.

TABLE 2 REGULATORY AGENCY REQUIREMENTS FOR INJECTION WATER

CONSTITUENT	MAXIMUM CONCENTRATION (mg/l)
Ammonium	1.0
Sodium	110.0
Total hardness ($CaCO_3$)	220.0
Sulfate	125.0
Chloride	120.0
Total nitrogen (N)	10.0
Fluoride	0.8
Boron	0.5
MBAS	0.5
Hexavalent chromium	0.05
Cadmium	0.01
Selenium	0.01
Phenol	0.001
Copper	1.0
Lead	0.05
Mercury	0.005
Arsenic	0.05
Iron	0.3
Manganese	0.05
Barium	1.0
Silver	0.05
Cyanide	0.02
Electrical conductivity	900 umhos/cm
pH	6.5 - 8.0
Taste	None
Odor	None
Foam	None
Color	None
Filter effluent turbidity	1.0 JTU
Carbon adsorption column effluent COD	30 mg/l
Chlorine contact basin effluent	Free chlorine residual

TABLE 3 SECONDARY EFFLUENT QUALITY – ORANGE COUNTY SANITATION DISTRICTS TREATMENT PLANT NO. 1

Constituent	CONCENTRATION, mg/l
Calcium	70 - 110
Magnesium	20 - 45
Sodium	240 - 260
Potassium	20 - 35
Bicarbonate	200 - 450
Sulfate	270 - 300
Chloride	300 - 350
Phosphate	20 - 25
Nitrogen	
Organic	5 - 15
Ammonia	15 - 30
Nitrite	<1
Nitrate	<1
Total Dissolved Solids	1200 - 1400
Suspended Solids	30 - 80
BOD	30 - 80
COD	100 - 200
MBAS	3 - 4

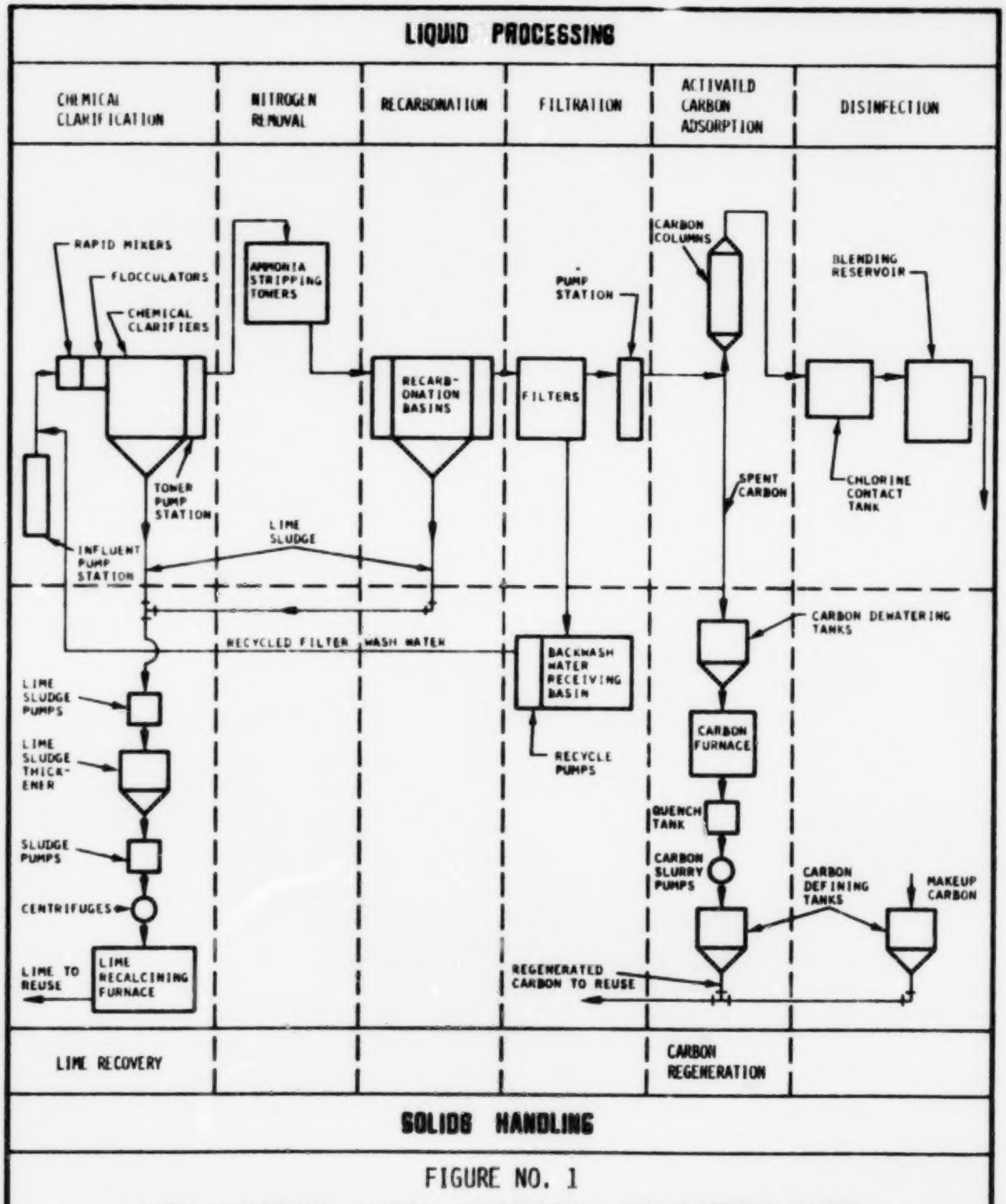

LIQUID PROCESSING
CHEMICAL CLARIFICATION
NITROGEN REMOVAL
RECARBONATION
FILTRATION
ACTIVATED CARBON ADSORPTION
DISINFECTION
RAPID MIXERS
FLOCCULATORS
CHEMICAL CLARIFIERS
AMMONIA STRIPPING TOWERS
RECARBONATION BASINS
FILTERS
PUMP STATION
CARBON COLUMNS
BLENDING RESERVOIR
TOWER PUMP STATION
INFLUENT PUMP STATION
LIME SLUDGE
SPENT CARBON
CHLORINE CONTACT TANK
RECYCLED FILTER WASH WATER
BACKWASH WATER RECEIVING BASIN
RECYCLE PUMPS
CARBON DEWATERING TANKS
LIME SLUDGE PUMPS
LIME SLUDGE THICKENER
SLUDGE PUMPS
CENTRIFUGES
LIME TO REUSE
LIME RECALCINING FURNACE
CARBON FURNACE
QUENCH TANK
CARBON SLURRY PUMPS
CARBON DEFINING TANKS
MAKEUP CARBON
REGENERATED CARBON TO REUSE
LIME RECOVERY
CARBON REGENERATION
SOLIDS HANDLING

FIGURE NO. 1

FLOW SCHEMATIC 15 MGD WASTEWATER RECLAMATION PLANT

TABLE 4 MAJOR DESIGN CRITERIA, OCWD 15 MGD WASTEWATER RECLAMATION PLANT

INFLUENT PUMP STATION

Number of pumps: 2
Capacity: 6500 gpm @ 29 ft TDH 7000 gpm @ 27 ft TDH
Type: Vertical mixed flow

CHEMICAL CLARIFICATION SYSTEM

Rapid Mixing

Number of basins: 2 in series
Mechanical mixer in each basin
Dimension: length = 12 ft; width = 12 ft; depth = 12 ft
Detention time: 2.4 minutes total @ 15 mgd
Chemical addition: First basin - lime, alum, recycled lime sludge
Second basin - polymer

Flocculation

Number of basins: 2, three compartments each
Detention time: 10 min/compartment (30 min total) @ 15 mgd
Chemical addition: Polymer, 1st and 3rd compartments
Dimensions: length = 48 ft; width = 41 ft; depth = 11 ft
Flocculator mechanism: Oscillating type

Settling Basins

Number of basins: 2 rectangular
Dimensions: 120 ft long X 40 ft wide, each
Surface Overflow Rate: 1563 gpd/sq ft @ 15 mgd
Each basin equipped with settling tubes

Clarifier Effluent Pump Station

Number of pumps: 4
Capacity: 3300 gpm @ 75 ft TDH; 3500 gpm @ 65 ft TDH
Discharge: To ammonia stripping tower or to the OCSD plant or to the recarbonation basins

Lime Feeders and Slakers

Number: 2 gavimetric feeders and paste type slakers
Capacity: 4000 lbs/hour each

Polymer Feed System

Number of mixing tanks: 2 (900 gallons each)
Number of feed pumps: 4
Capacity: 5 to 50 gph each

Alum Feed System

Number of storage tanks: 2 (4,100 gallons each)
Number of feed pumps: 3 (2 double head and 1 single head)
Capacity: 25 gph each head

TABLE 4 (CONTINUED)

AMMONIA STRIPPING/COOLING TOWERS

Number of towers: 2
Dimensions: length - 207 ft; width = 61 ft; depth of packing = 25 ft
Capacity: 5200 gpm each @ 0.1 gpm/sq ft
Number of fans: 6 per tower, 18 ft diameter, 2 speed electric motors
Air Capacity: 2,100,000 cfm/tower (400 cfm/gpm)
Hot water streams: Tower No. 1 - 8,000 gpm cool 115°F to 80°F
Tower No. 2 - 11,000 gpm cool 120°F to 85°F

RECARBONATION

Number: 2 (3 compartment basins: 1st stage recarbonation, intermediate settling, 2nd stage recarbonation)
Detention Time, 1st and 2nd stage recarbonation: 15 minutes each
Overflow rate, intermediate settling: 3000 gpd/sq ft @ 15 mgd

FILTRATION

Number of filters: 4
Dimensions: 22 ft X 24 ft
Type: open, gravity, mixed media
Hydraulic loading rate: 5 gpm/sq ft @ 15 mgd
Maximum operating head loss: 10 ft
Filter aids: alum and polymers
Backwash system: Hydraulic with rotating surface wash arms
Backwash rate - 15 gpm/sq ft
Surface wash rate - 0.6 gpm/sq ft
Backwash water receiving tank volume: 160,000 gallons

ACTIVATED CARBON ADSORPTION

Number of contactors: 17
Normal Service: 16 in parallel operation, 1 for carbon storage and standby service
Type: Upflow, countercurrent, in steel pressure vessels
Dimensions: Overall height = 41 ft; sidewall height = 34 ft; Diameter = 12 ft
Contact Time: 30 minutes at 15 mgd
Carbon Size: 8 X 30 mesh

CHLORINATION

Number of contact basins: 1
In-line feeding and mixing
Contact Time: 30 minutes
Chlorine Feeders: 3 (2000 lbs/day each)
On site generation of chlorine: 2,000 lbs/day

CHEMICAL SLUDGE TREATMENT AND RECOVERY SYSTEMS

Sludge Pumps

Number: 3
Capacity: 500 gpm to 700 gpm
Influent solids capability: 5% maximum

TABLE 4 (CONTINUED)

Sludge Thickener

Number: 1
Dimensions: 45 ft diameter, 8 ft 4 in sidewater depth
Loading: 600 gpd/sq ft @ 1.5% solids from clarifier at flow of 15 mgd; dry solids loading = 75 lbs/sq ft/day
Thickened sludge concentration: 8 to 13% solids

Thickened Sludge Pumps

Number: 3
Capacity: 80 gpm at 60 ft head each, variable speed
Influent solids capability: 18% maximum

Centrifuges

Number: 2
Capacity: 2,000 lbs/hour each
Feed Rate: 54 to 105 gpm

Recalcining Furnace

Number: 1, 6 hearth
Dimensions: 22 ft 3 in. OD; 20 ft 0 in. ID
Capacity: 0.4 to 2.0 tons/hour; 30 tons/day dry CaO
Scrubber: 3 stage jet impingement
Fuel: natural gas

Lime Storage Bins

Number: 2
Capacity: 35 tons each
Dimensions: 12 ft 6 in. diameter by 15 ft 1 in. storage depth (overall height = 28 ft 6 in.)

Carbon Dioxide Compressors

Number: 3
Capacity: 1,600 cfm (12% CO_2) each

ACTIVATED CARBON REGENERATION

Regeneration Furnace

Number of furnaces: 1, 6 hearth
Dimensions: 9 ft 3 in. OD, 7 ft ID
Capacity: 2,000 to 12,000 lbs/day (dry basis)
Steam Addition: No. 4 and No. 6 hearths (optional); 1 lb steam per lb carbon
Air Pollution Control:
    Scrubber: Venturi followed by water separator

    Afterburner: Vertical, refractory lined steel, 1400°F at 0.5 seconds minimum gas retention time

TABLE 4 (CONTINUED)

Carbon Wash and Transfer Tanks

Number: 2
Dimensions: 5 ft diameter by 10 ft high
Equipped with bag dump and dust collector

Regenerated Carbon Wash Tanks

Number: 2
Dimensions: 5 ft diameter by 10 ft high

Spent Carbon Dewatering Tanks

Number: 2 (open top)
Dimensions: 5 ft X 5 ft X 14 ft 6 in. high
Furnace feed system: 12 in. diameter screw conveyor, stainless steel with capacity of 80 to 500 lbs/hr on a dry basis

Carbon Slurry Pumps (transfer carbon from regeneration furnace to carbon wash tanks)

Number: 2
Type: Diaphragm slurry, air operated, 3 in. suction and discharge
Capacity: 500 gpm with 4:1 turndown ratio

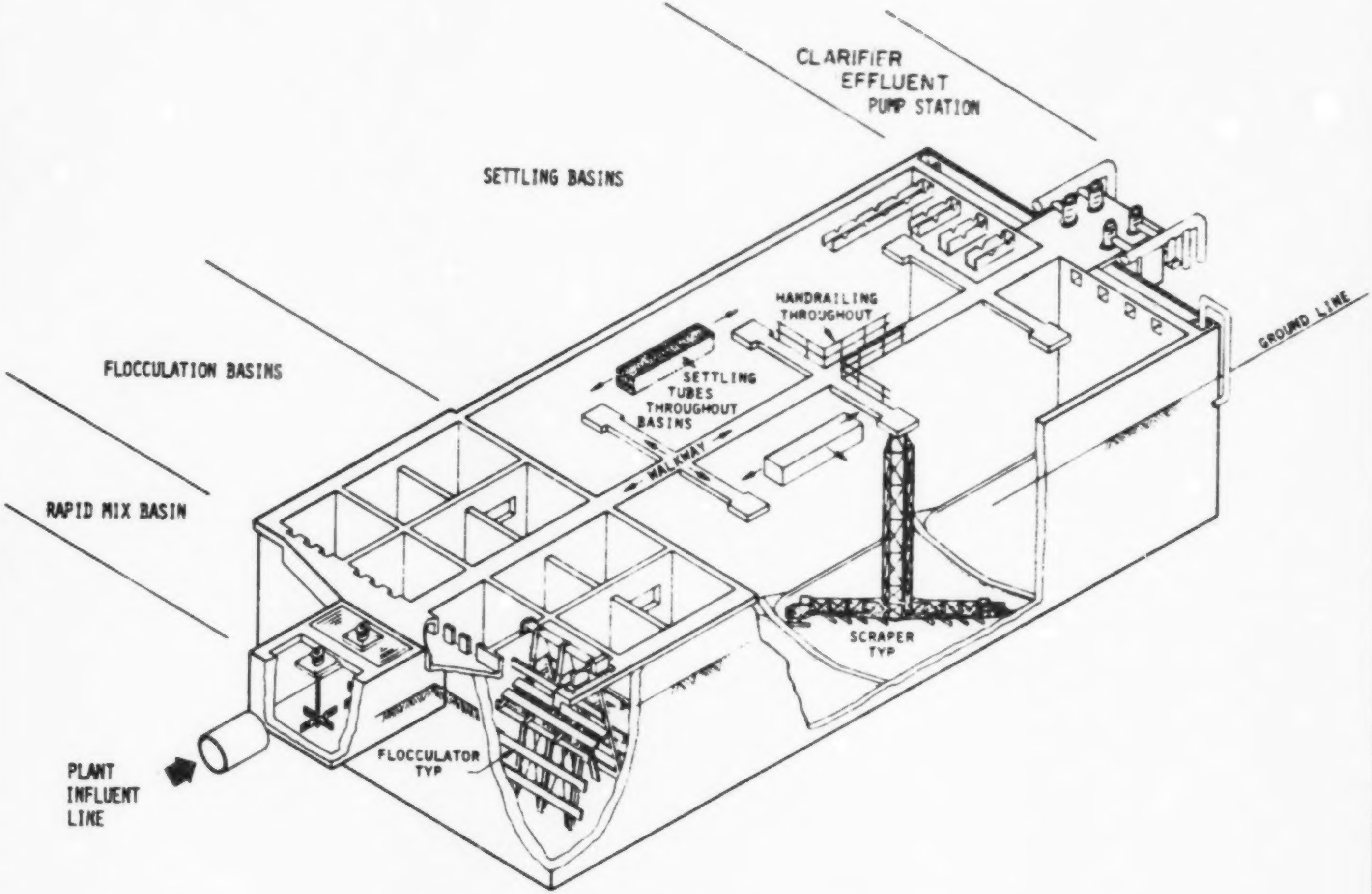

CLARIFIER EFFLUENT PUMP STATION
SETTLING BASINS
FLOCCULATION BASINS
RAPID MIX BASIN
HANDRAILING THROUGHOUT
SETTLING TUBES THROUGHOUT BASINS
WALKWAY
GROUND LINE
SCRAPER TYP
FLOCCULATOR TYP
PLANT INFLUENT LINE

FIGURE NO. 2

CHEMICAL CLARIFICATION BASIN

Rapid Mix

Secondary trickling filter effluent is pumped from OCSD into the first rapid mix basin where lime, in slurry form, is added and mixed. The rapid mix basins are equipped with removable mechanical mixers to facilitate cleaning. The rapid mix detention time at plant design flow (15 mgd) is 2.4 minutes total.

Liquid alum and recycled lime sludge can also be added to the first basin if it is determined that either or both will improve floc formation and settling. There are also provisions for addition of polymer to the second rapid mix basin.

Lime feed to the rapid mix basin is accomplished by two gravimetric lime feeders and paste type slakers. Water is added to the slaked lime to form a slurry and the slurry flows to the rapid mix basin in a flume. One feeder is for makeup lime, the other is for recalcined lime. Usually both machines will be in operation, but, if necessary, either one alone can treat the entire plant flow. The feed rate can be adjusted manually or it can be paced to plant flow rate by means of an automatic pacing device.

There are four polymer feed and metering pumps which can be automatically paced to flow. It is anticipated that good flocculation, clarification, and phosphorus removal will be accomplished using lime as the primary coagulant and a polymer as a coagulant aid. It is anticipated that only under unusually difficult circumstances, if ever, will it be necessary to add alum to the rapid mix basin.

Flocculation

The chemically treated secondary effluent flows from the rapid mix basins to a distribution channel where the flow is divided into two parallel flocculation basins. Each flocculation basin normally treats one-half the flow. One basin can be taken out of service by closing the sluice gates in the distribution channel. Each basin is divided into three bays or compartments and each bay contains an oscillating paddle type mixer. The detention time in each bay is ten minutes. The oscillating paddle mixers are variable speed to allow independent control of mixing energy in each bay. Normally the paddle speed is fastest in basin no. 1 and slowest in basin no. 3.

Settling

Water flows from the bottom of the flocculation basin and enters near the bottom of two parallel settling basins. Water flows horizontally and up through settling tubes over notched weirs and out through collection troughs to the clarifier effluent pump station. The settling basins design overflow rate is 1563 gpd/ft^2 @ 15 mgd. Solids settle to the bottom and are removed continuously by three mechanical scrapers in each basin. The settled solids then flow by gravity to the sludge pump station.

Clarifier Effluent Pump Station

The chemically clarified effluent flows by gravity to the pump station located at the south end of the settling basin. The pump station is divided into two separate sumps and each sump is equipped with two pumps. Effluent from the chemical clarifier can be pumped to any one of three places:

1. Ammonia stripping towers
2. Returned to the OCSD plant for ocean disposal
3. The recarbonation basin (bypass the ammonia stripping towers).

The chemical clarifier effluent can be returned to the OCSD plant through control valves in each of the clarifier effluent pump discharge lines. It will be necessary to return the clarifier effluent to OCSD for a few hours after start-up of the clarifier. The clarifier effluent turbidity should be less than ten JTU for the subsequent unit operations to perform efficiently. During start-up, the clarifier effluent turbidity is initially too high; also, occasionally, upsets in the secondary treatment or equipment failures may necessitate returning the flow to OCSD.

A control circuit is provided to automatically return the clarifier effluent to the OCSD plant when the turbidity of the clarifier effluent is above the normal range. This normal range is adjustable and the circuit can either be activated or deactivated by a panel-mounted switch. Flow will be pumped to the ammonia stripping towers when the turbidity is within the normal range.

Ammonia Stripping/Cooling Towers

The two ammonia stripping/cooling towers serve the dual purposes of removing nitrogen in the form of ammonia gas from the lime clarified wastewater and cooling two warm water streams from the seawater desalting process. An illustrative section of the towers is shown in Figure 3.

Tower No. 1 cools process water from 115° to 85°F. This process water is returned to the desalting plant. Tower No. 2 cools waste brine from about 120° to 85°F, prior to discharge in the ocean through OCSD's outfall. In the water cooling operations, the inlet air to the ammonia stripping units will be heated to approximately 90°F and the warm air will increase the efficiency of the ammonia stripping process. The ammonium ions present in the secondary effluent are converted to ammonia gas when the pH of the wastewater is raised to 10.8 to 11.5. The ammonia gas can then be removed from the wastewater by air stripping.

Each of the six cells in each tower is equipped with a two speed fan capable of a maximum air capacity of about 350,000 cfm. This provides an air to water ratio of 400 ft^3/gal of wastewater. Air is drawn into the tower through the separate cooling sections which are located at the lower outside faces of the towers. Airflow passes up through the packing (countercurrent to water flow) for air stripping of ammonia from the water droplets as they are formed by the splash bar packing. The splash bar packing is arranged in removable modules. The modules are 6 x 5 x 4 feet. The arranged modules are stacked six high in each cell for a total packing depth of 25 feet. The air exhausts through the fan stacks on top of the tower structure.

Chemical clarifier effluent is pumped to the top of the towers and a pressure header in each tower distributes the flow through spray nozzles to the cells. Each tower has six cells and each cell is equipped with two, 12 ft. wide packing sections which are separated by an interior central access area and flanked by exterior access areas. Water flows down through the packing sections at the rate of 1 gpm/ft^2 of packing area through either of two lines which serve the respective towers, to the recarbonation basin.

Water or airflow can be shut off to any individual cell. Five of the six cooling cells in either tower are adequate for the cooling duty, so that any one cell can be taken out of service as necessary for maintenance.

If scale builds up excessively on the ammonia stripping packing, the packing modules may either be cleaned by hosing in place or it may be removed, by means of the equipment provided, for external cleaning by hydraulic or mechanical means. By cleaning only one cell of the tower at a time, the other five cells can remain in service. The system is also equipped with facilities to add a descaling polymer to the tower influent if needed.

Recarbonation

The primary purpose of the recarbonation basin is to inject carbon dioxide (CO_2) gas into the wastewater to lower the high pH resulting from the lime treatment in the chemical clarifier. The two-stage system with intermediate settling also provides for maximum recovery of calcium and reduces the total dissolved (TDS) content of the water below that which would result from the same pH reduction in a single stage. The recarbonation basin is shown in Figure 4.

The flow into the first recarbonation basin is usually by gravity from the ammonia stripping towers, although flow may be pumped directly from the chemical clarifier if the stripping towers are not in service. Flow enters the first stage recarbonation basin where enough CO_2 is injected to lower the pH to about 10.2. The first stage recarbonation basins are equipped with mechanical flocculation devices which are identical to those in the chemical clarifier flocculation basins. The CO_2 is obtained from the recalcining furnace stack gas and is injected through a 4 in. PVC perforated pipe which serves as a diffuser. A standby connection is

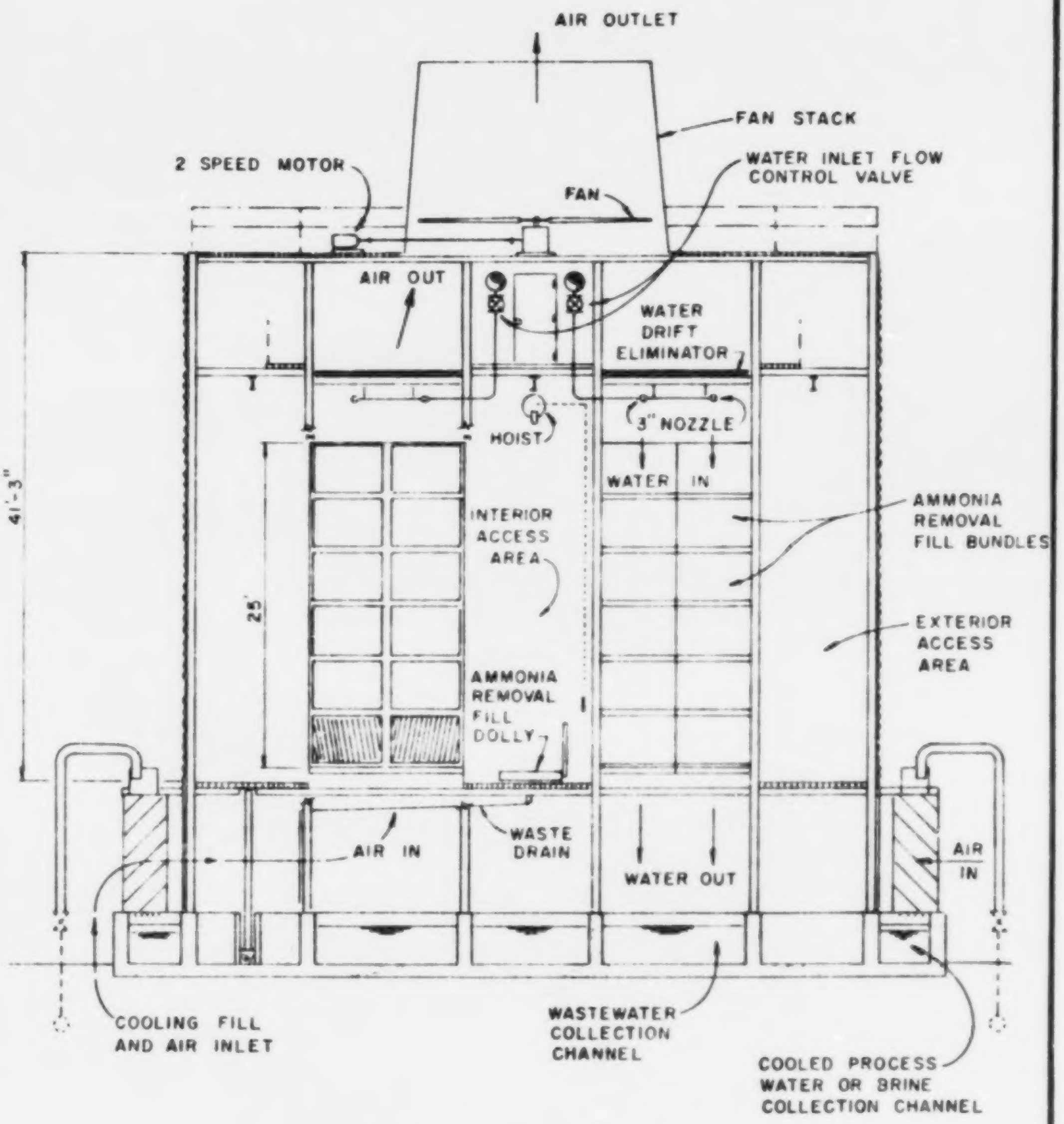

AIR OUTLET
FAN STACK
2 SPEED MOTOR
WATER INLET FLOW CONTROL VALVE
FAN
AIR OUT
WATER DRIFT ELIMINATOR
HOIST
3" NOZZLE
WATER IN
41'-3"
25'
INTERIOR ACCESS AREA
AMMONIA REMOVAL FILL BUNDLES
EXTERIOR ACCESS AREA
AMMONIA REMOVAL FILL DOLLY
AIR IN
WASTE DRAIN
WATER OUT
AIR IN
COOLING FILL AND AIR INLET
WASTEWATER COLLECTION CHANNEL
COOLED PROCESS WATER OR BRINE COLLECTION CHANNEL

FIGURE NO. 3

AMMONIA STRIPPING TOWER

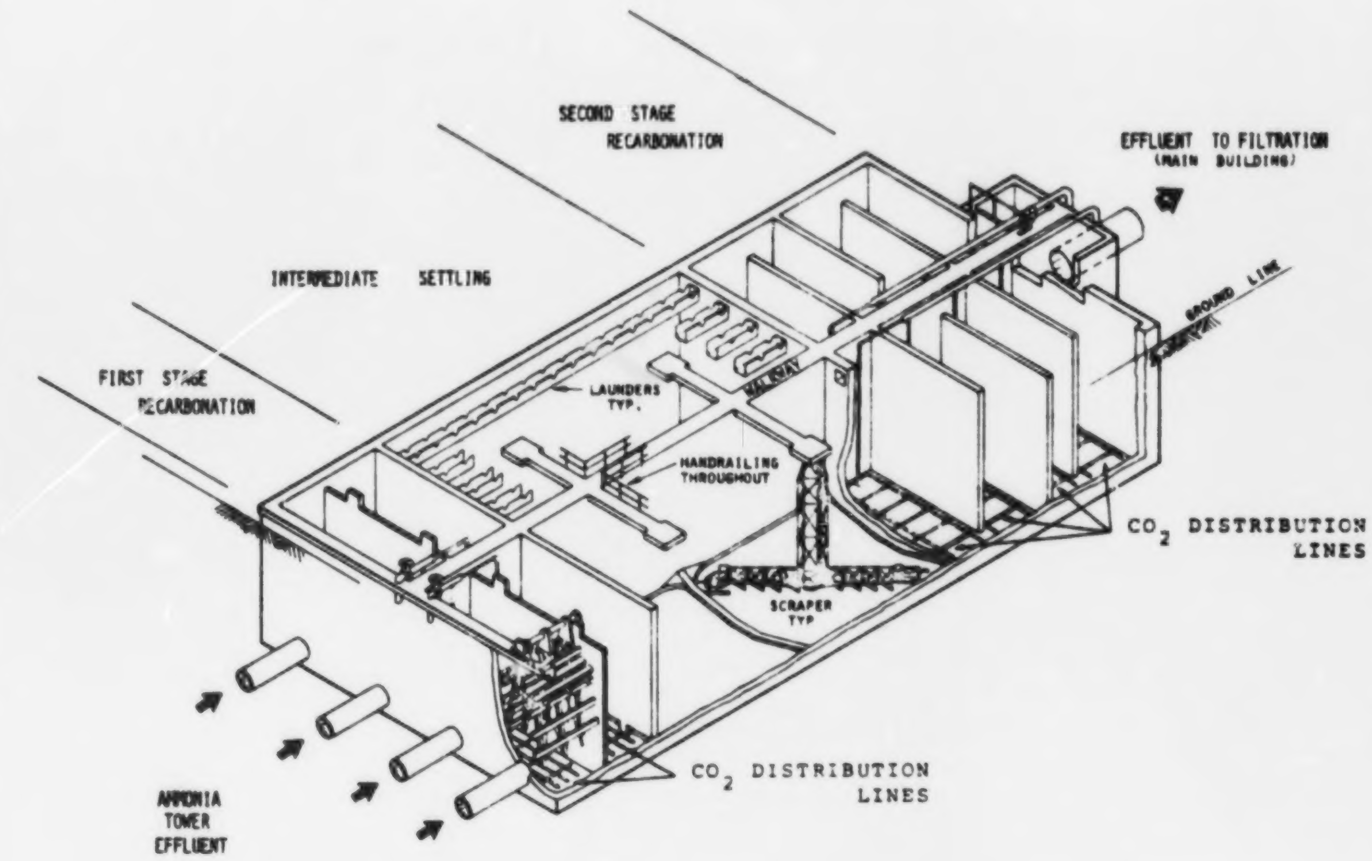

SECOND STAGE RECARBONATION
EFFLUENT TO FILTRATION (MAIN BUILDING)
INTERMEDIATE SETTLING
FIRST STAGE RECARBONATION
LAUNDERS TYP.
WALKWAY
GROUND LINE
HANDRAILING THROUGHOUT
CO_2 DISTRIBUTION LINES
SCRAPER TYP
AMMONIA TOWER EFFLUENT
CO_2 DISTRIBUTION LINES

FIGURE NO. 4

RECARBONATION BASIN

provided for emergency use of pure liquid CO_2 which would be purchased in a bulk storage tank. A foam control spray is provided in this basin.

The flow then passes through slots along the bottom of a common wall into the intermediate settling basin where the calcium carbonate ($CaCO_3$) floc is allowed to settle. Each of the two intermediate settling basins is equipped with mechanical sludge scrapers. Most of the settled sludge - which is almost pure $CaCO_3$ - is pumped to the lime recalcining system, although a small portion may be recycled to the chemical clarifier rapid mix basins to aid the clarification process.

The effluent from the settling basin is collected in four launders in each basin and conveyed to the adjacent secondary recarbonation basin where additional CO_2 is injected to lower the pH to near 7. The final recarbonated effluent then flows by gravity to the filter distribution box. The pH of the recarbonation basin effluent is continuously monitored to provide control of the process.

Filtration

It is the purpose of the filtration system to provide the maximum water clarity achievable. This is important for several reasons: (1) the discharge requirements specify that the product water turbidity not exceed 1 JTU, (2) filtration ahead of carbon adsorption reduces the load of organics, suspended solids, and colloidal matter reaching the carbon which increases carbon efficiency and reduces carbon fouling, and (3) the effectiveness of disinfection by chlorination is significantly improved by removing particulate matter which otherwise may encapsulate virus and bacteria, preventing the necessary contact with the chlorine.

The recarbonation system effluent passes through four open, gravity, downflow filter beds which operate in parallel. Figure 5 shows a cross-sectional view of the filters including the pipe gallery. Each bed has a capacity of 3.75 mgd at a throughput rate of 5 gpm per square foot of surface area. The filters are the mixed media type which provide coarse-to-fine filtration in the direction of flow. The filter media (30 inches deep) is made up of coarse coal, medium sand and fine garnet.

As a filter operates in removing suspended matter from the wastewater, the headloss or pressure drop increases. Eventually the headloss reaches the point (about 10 feet) that the filter must be backwashed to remove the accumulated solids. Normally the filters are backwashed for about six minutes at a rate of 15 gpm per square foot (7,920 gpm). In addition, the filters are equipped with rotary surface wash devices.

All backwash water and all water following backwash, when the filter is operated in a filter-to-waste mode, flows to the backwash water receiving tank. From there the backwash water is recycled back to the rapid mix basins and recovered. Generally, following the backwash operation, the filter is operated in the filter-to-waste cycle for about 15 to 20 minutes as determined by the filter effluent turbidity. For best virus removal by chlorination, it is desirable to filter-to-waste until the turbidity of the effluent is less than 0.2 JTU before returning the filter to service.

Filtered water flows to a basin in the main building. The filtered water basin sump is equipped with two sets of pumps which pump effluent to the activated carbon columns and also provide water to the plant water supply system.

Activated Carbon Adsorption

The filtered effluent is pumped to columns of granular activated carbon. In biological treatment of wastewater by activated sludge or trickling filters, some dissolved organic materials are removed including most of those measured by the BOD (biochemical oxygen demand) test. These materials include MBAS (Methlene blue active substances - primarily from detergents), herbicides, pesticides, tannins, lignins, ethers, proteinaceous substances, and other color and odor producing organics. It is the purpose of the activated carbon adsorption process to remove these organic materials which are not adequately removed in the biological process. Activated carbon adsorption

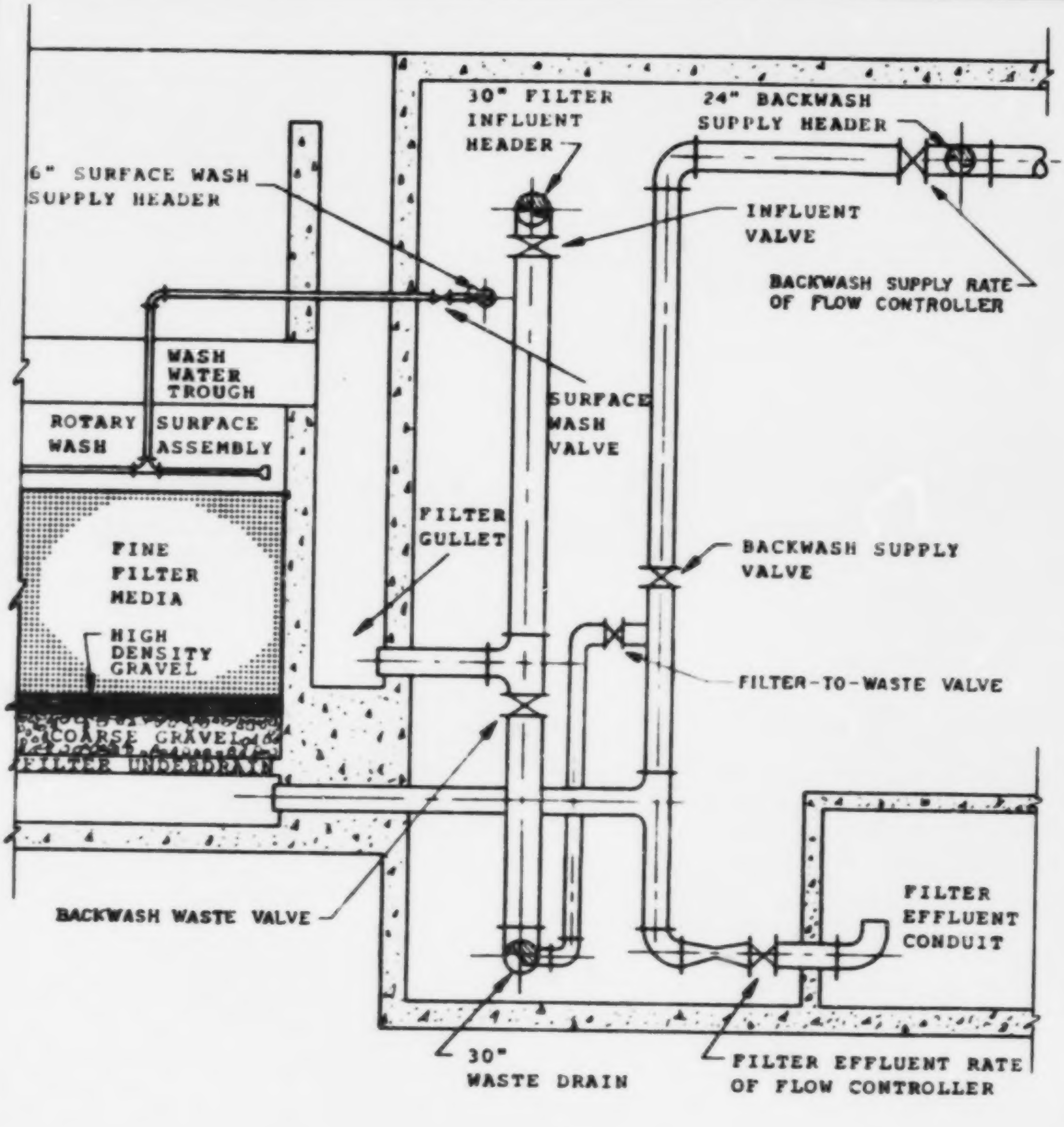

30" FILTER INFLUENT HEADER
24" BACKWASH SUPPLY HEADER
6" SURFACE WASH SUPPLY HEADER
INFLUENT VALVE
BACKWASH SUPPLY RATE OF FLOW CONTROLLER
WASH WATER TROUGH
SURFACE WASH VALVE
ROTARY WASH
SURFACE ASSEMBLY
FILTER GULLET
FINE FILTER MEDIA
BACKWASH SUPPLY VALVE
HIGH DENSITY GRAVEL
FILTER-TO-WASTE VALVE
COARSE GRAVEL
FILTER UNDERDRAIN
FILTER EFFLUENT CONDUIT
BACKWASH WASTE VALVE
30" WASTE DRAIN
FILTER EFFLUENT RATE OF FLOW CONTROLLER

FIGURE NO. 5

MIX MEDIA FILTER

also has the ability to provide some removal of trace inorganic metals such as cadmium, chromium and silver.

The removal of soluble, refractory organics is important because the organic content of the reclaimed water should be minimized to eliminate taste, odor and foam, and the removal of organics reduces the chlorine demand of the wastewater, reducing the cost for effective disinfection.

There are 17 carbon adsorption columns, 16 of which operate in parallel, with the remaining unit used for carbon storage and stand-by service. The columns are upflow pressure units. Water is introduced to the column through the bottom inlet screens, flows upward through the carbon and leaves the column through the top screens. The contact time is about 30 minutes (empty bed basis) at a flow of 15 mgd. The upflow columns are operated in the current mode. Figure 6 is an illustration of a typical carbon column. The carbon columns are 12 feet diameter steel epoxy lined tanks. Each tank contains approximately 45 tons of granular activated carbon.

Activated Carbon Regeneration and Reuse

About every 4-6 weeks it will be necessary to thermally regenerate a portion of the carbon. Granular activated carbon removes detergents, insecticides, herbicides and various organic substances which contribute to the taste, odor and color of the wastewater. As these substances are removed by adsorption, the carbon increases in weight and with continued use eventually becomes saturated and loses its ability to further adsorb organic materials. The carbon nearest to the inlet (bottom) of the carbon column becomes saturated and loses its ability to further adsorb organic materials. The carbon nearest to the inlet (bottom) of the carbon column becomes saturated or exhausted first. The exhausted carbon at the bottom of the column is removed for regeneration and following regeneration is returned to the top of the column (counter current operation).

The purpose of the regeneration process is to restore the adsorptive capacity of the granular carbon. Regeneration is accomplished by heating the carbon to temperatures in excess of 1,500°F. The heat vaporizes and drives off the impurities which have been adsorbed on the carbon and restores the carbon essentially to its original activity.

When carbon in the bottom of a carbon column becomes saturated with impurities and no longer has capacity to adsorb organics from the incoming wastewater, a portion (one dewatering bin full or about 10 percent of the carbon in one column) is withdrawn and discharged to a dewatering bin. Carbon is transferred from one container to another in slurry form. About one gallon of water per pound of carbon is required to form a suitable slurry. A schematic diagram of the carbon regeneration and reuse system is shown in Figure 7.

The dewatering bins are epoxy coated to protect the steel against the corrosive action of partially dewatered carbon. In about ten minutes the free water will drain from the carbon through the screened drains. Because of the fine pore structure of the carbon, it still retains 40 to 45 percent moisture after draining and this moisture content is about optimum for its thermal regeneration. The partially dewatered carbon is transferred from one of the two dewatering tanks by means of a variable speed, stainless steel, screw conveyor at rates which can be varied from 80 to 500 pounds per hour (dry basis). The exhausted carbon is discharged into the top of the carbon regeneration furnace.

The carbon regeneration furnace is a gas fired six hearth unit rated at 12,000 pounds per day of dry carbon. There are six burners, two each on hearths 4, 5 and 6. The temperatures on these hearths are independently regulated within 10°F by an automatic temperature controller. Recording of all hearth temperatures is also provided. Proportional flow meters on the air-gas mixture lines to the burners insure a constant percentage of excess oxygen. The oxygen content of the furnace atmosphere must be limited to avoid overburning of the carbon. Each burner may be adjusted to maintain 0 to 5 percent oxygen by volume. In addition, steam can be added to hearths 4 and 6 to give more uniform distribution of temperature throughout the furnace. The carbon is moved across the hearths by four rotating stainless steel rabble arms on

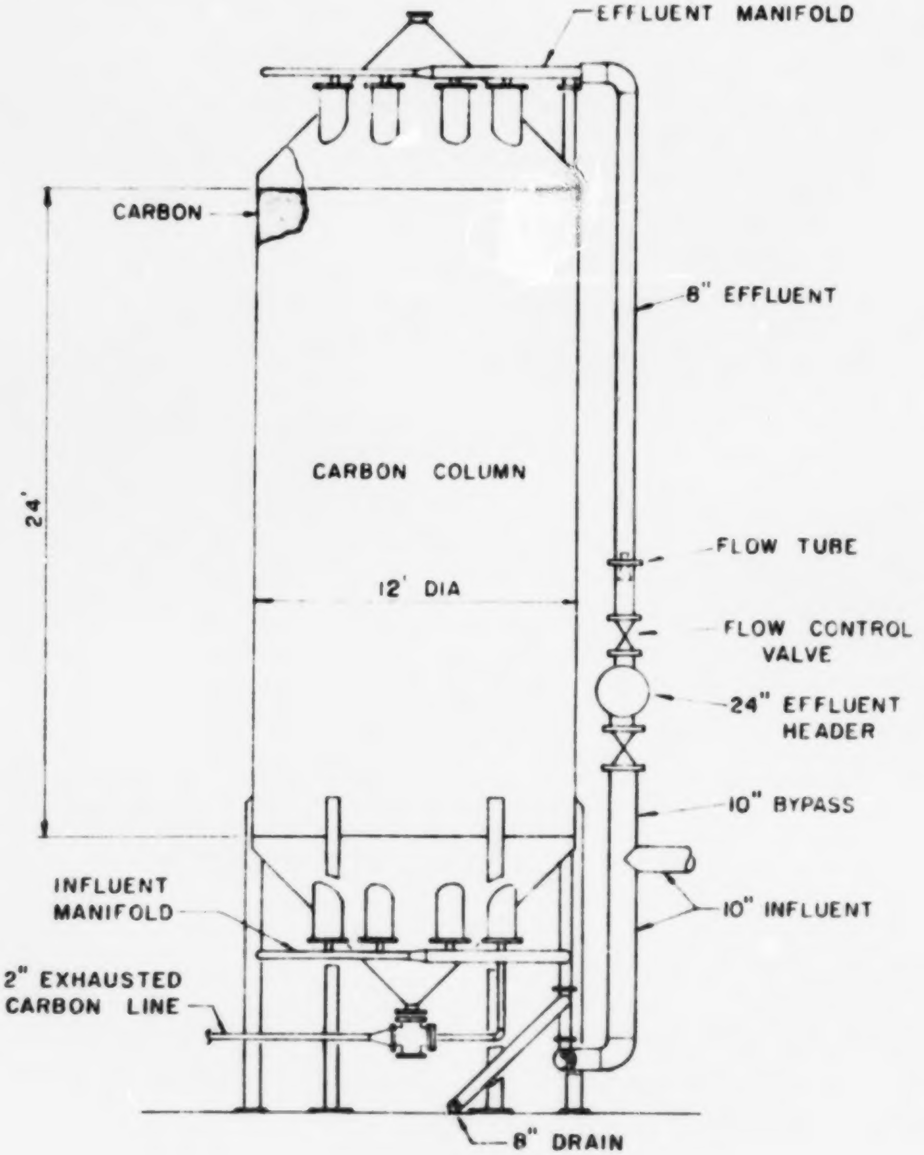

EFFLUENT MANIFOLD
CARBON
8" EFFLUENT
CARBON COLUMN
24'
FLOW TUBE
12' DIA
FLOW CONTROL VALVE
24" EFFLUENT HEADER
10" BYPASS
INFLUENT MANIFOLD
10" INFLUENT
2" EXHAUSTED CARBON LINE
8" DRAIN

FIGURE NO. 6

CARBON COLUMN

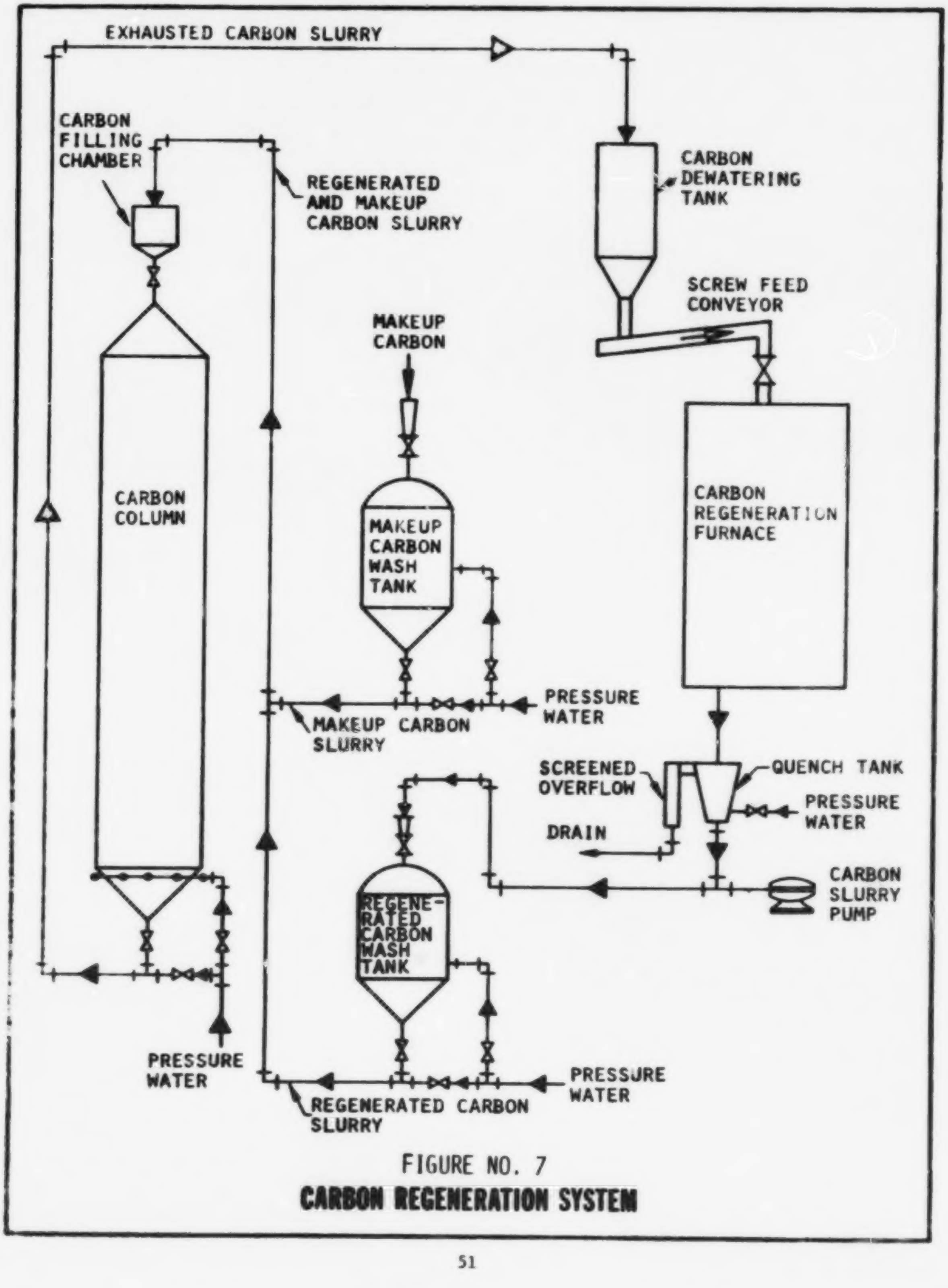

EXHAUSTED CARBON SLURRY
CARBON FILLING CHAMBER
REGENERATED AND MAKEUP CARBON SLURRY
CARBON DEWATERING TANK
SCREW FEED CONVEYOR
MAKEUP CARBON
CARBON COLUMN
MAKEUP CARBON WASH TANK
CARBON REGENERATION FURNACE
PRESSURE WATER
MAKEUP CARBON SLURRY
SCREENED OVERFLOW
QUENCH TANK
PRESSURE WATER
DRAIN
CARBON SLURRY PUMP
REGENERATED CARBON WASH TANK
PRESSURE WATER
PRESSURE WATER
REGENERATED CARBON SLURRY

FIGURE NO. 7

CARBON REGENERATION SYSTEM

each hearth. Each arm is equipped with stainless steel rabble teeth which are oriented vertically. The rabble arms are driven by a central shaft which is cooled by an electrically driven fan so that the exhaust cooling air temperature is 450° or less. The exhausted cooling air is ducted into the main exhaust stack to aid in drying the scrubber exhaust gases for plume control.

The gases produced by carbon regeneration leave the top of the furnace and enter an afterburner which operates at 1,400°F to burn volatile and noxious gases. The furnace is also equipped with a Venturi type wet scrubber to remove carbon fines. The scrubber water is returned to the rapid mix basin for reprocessing.

The regenerated carbon is discharged from the bottom of the furnace into a quench tank for cooling. The carbon slurry is pumped from the quench tank to either of two regenerated carbon wash tanks. After removal of fines in the wash tanks, the carbon is transferred back to the columns for reuse.

Chlorination

Effluent from the activated carbon flows to the chlorination basin. The purpose of chlorination is to destroy any remaining bacteria and virus and to remove (by chemical oxidation) any remaining ammonia. Figure 8 shows a plan view of the chlorine contact basin.

Chlorine is added through a perforated diffuser pipe in the 30-inch pipeline before it enters the chlorine contact basin. Immediately after the diffuser, the flow makes a 90° turn and passes over several baffles. The purpose of this diffusion and baffling system is to thoroughly mix the chlorine solution with the carbon column effluent. The contact basin is baffled to provide a serpentine flow path for the water. The theoretical detention time in the basin is 30 minutes at a flow rate of 15 mgd.

Blending and Storage Reservoir

Effluent from the chlorination basin flows by gravity through a 30-inch line to a one million gallon blending and storage reservoir which is 100 feet in diameter and 20 feet deep where it is blended with desalted seawater and well water.

The State Department of Public Health requires that reclaimed wastewater must be blended with at least an equal amount of desalted seawater or deep well water before it is injected. Water is withdrawn from the reservoir through a 48-inch line for injection. Chlorine may be added to the injection pump suction line as it leaves the reservoir.

Injection Pump Station

This station contains three injection pumps. Each injection unit is a vertical turbine-can type pump with gas engine variable speed drive rated at 4,000 to 7,200 gpm at 140 and 122 feet TDH, respectively. These pumps take suction from the blending reservoir and discharge into the injection well supply pipeline.

The total injection flow is measured, totalized and recorded at the main control panel. The injection flow is controlled by an injection header pressure indicating controller. The output of this controller is used to proportionally control the speed of the injection pumps. Control is provided to match the injection flow to the flow into the blending and storage reservoir.

Injection Wells

There are 23 injection well stations and all but one of these is contained in an underground vault. Each station contains 2, 3 or 4 well casings, each perforated in a different aquifer. A typical injection station is shown in Figure 9.

The flow in each casing is individually adjustable with a manually operated valve. Injection well flow and head are transmitted for each well to the central data logging system in the main building control room.

Sludge Handling, Lime Recovery and Reuse

Chemical sludges are produced from (1) the coagulation of the wastewater in the chemical clarification process, and (2) the recarbonation process. It is the purpose of the chemical sludge system to

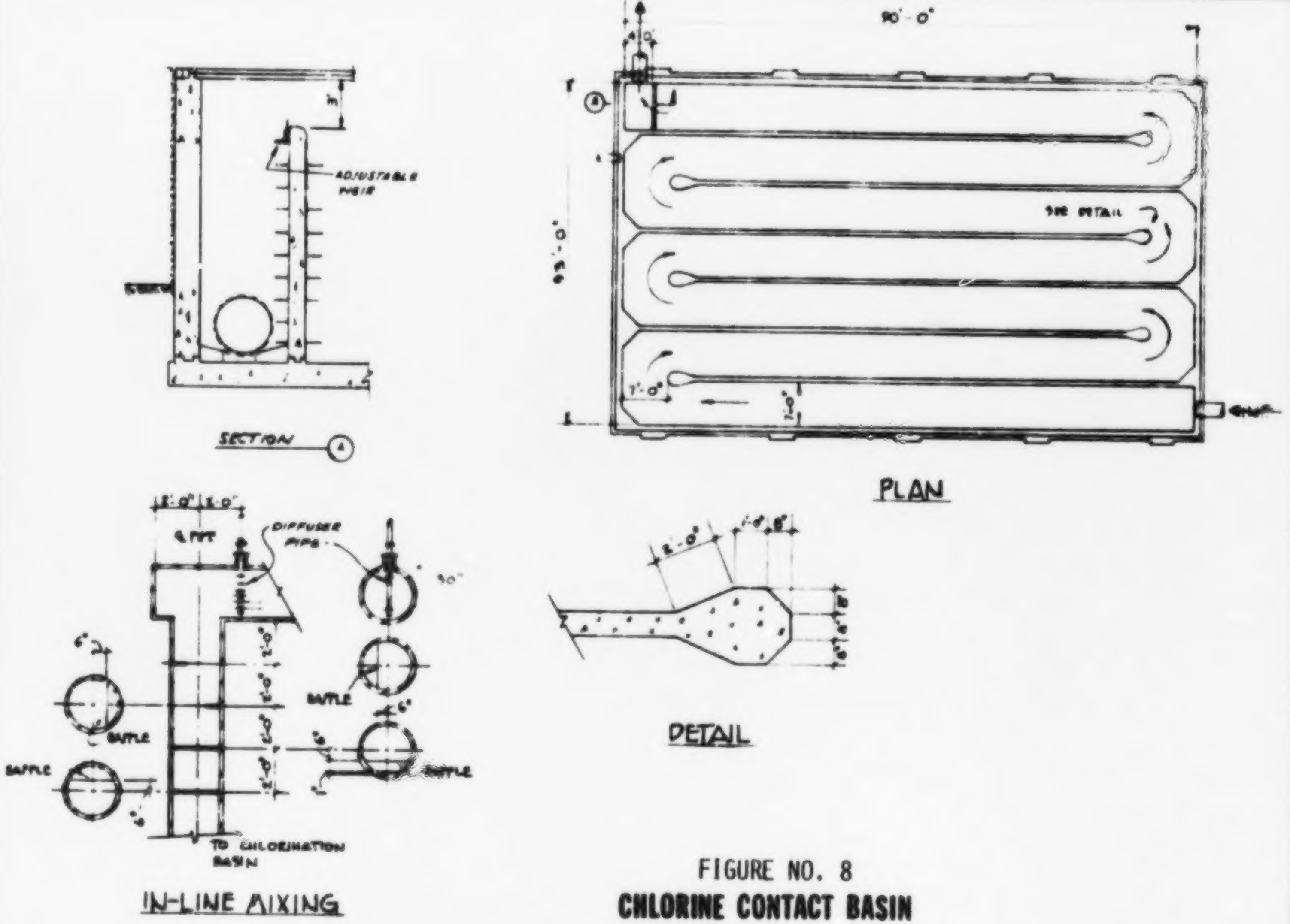
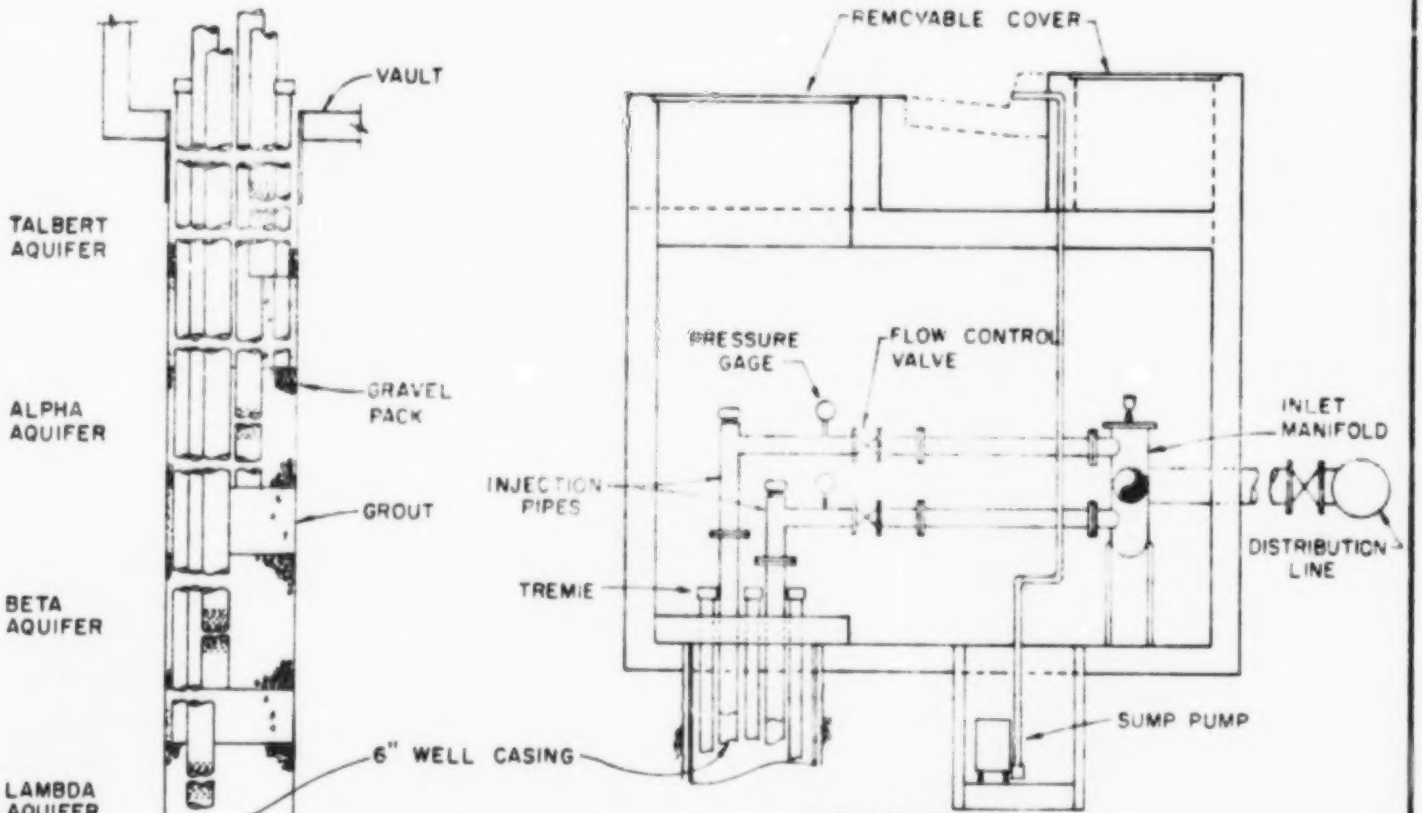

90'-0"
4'-0"
95'-0"
SEE DETAIL
7'-0"
1'-0"
PLAN
ADJUSTABLE WEIR
SECTION Ⓐ
DETAIL
2'-0"
1'-0"
8"
DIFFUSER PIPE
BAFFLE
30"
6"
2'-0"
TO CHLORINATION BASIN
IN-LINE MIXING

FIGURE NO. 8
CHLORINE CONTACT BASIN


VAULT
TALBERT AQUIFER
ALPHA AQUIFER
GRAVEL PACK
GROUT
BETA AQUIFER
LAMBDA AQUIFER
6" WELL CASING
REMOVABLE COVER
PRESSURE GAGE
FLOW CONTROL VALVE
INLET MANIFOLD
INJECTION PIPES
DISTRIBUTION LINE
TREMIE
SUMP PUMP

VAULT PIPING

INJECTION WELL

FIGURE NO. 9

INJECTION WELL

collect, concentrate and dewater these sludges so that lime can be recovered by a thermal recalcining process and reused; and the volume of residual waste materials requiring disposal can be minimized.

Figure 10 is a schematic diagram of the sludge handling and reuse system.

Sludge from the chemical clarifier settling basins and the recarbonation settling basins is pumped from the sludge pump station to a gravity thickener. Thickened sludge which is about 10 to 15 percent solids, is pumped to centrifuges and dewatered to about 50 percent solids.

The dewatered sludge is transferred by screw conveyor either to the lime recalcining furnace or to trucks for disposal at the County dump. Reclaimed lime is usually transferred by screw conveyor to lime storage bin No. 1, but it can also be transferred to bin No. 2. Lime is withdrawn from the storage bins, fed to a slaker and then transferred to the rapid mix basin in an open flume.

There were six bids for the construction of Water Factory 21's reclamation facilities. The bids were opened on March 14, 1972 and the total bid prices are shown below:

CONTRACTOR	RECLAMATION PLANT AND DISTRIBUTION FACILITIES
A	$11,705,900
B	12,655,160
C	13,181,000
D	13,805,000
E	13,988,600
F	14,357,000

The above bids include the distribution pipeline to the injection wells, and the well vaults and piping and other injection well appurtenances. The maintenance building and laboratory for the plant are not included in the above bids; also not included is the chlorine generation system or the fine filter media. Adding and deducting the cost of these items makes the total cost, including engineering design and inspection, for the 15 mgd wastewater reclamation facilities $11,924,000. A breakdown of these capital costs by treatment operation is shown in Table 5. The estimated operation and maintenance costs are shown in Table 6 and the total costs are shown in Table 7.

The estimated costs of water produced in the reclamation facilities are summarized below:

	WATER COSTS	
	$/acre foot	$/million gallons
Capital	57	175
Operation & Maint.	68	209
TOTAL	125	384

These costs are based on the following assumptions:

1. Service life of facilities = 30 years;
2. Interest rate = 6%;
3. Facilities operate 330 days/year and produce 15 mgd.

REFERENCES

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3. Wesner, G. M., and Baier, D. C., "Injection of Reclaimed Wastewater into Confined Aquifers", JAWWA, pp. 203-310, March 1970.

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6. Wesner, G. M., and Argo, D. G., "Pilot Wastewater Reclamation Study, May 1970 - June 1971", Orange County Water District, July 1973.

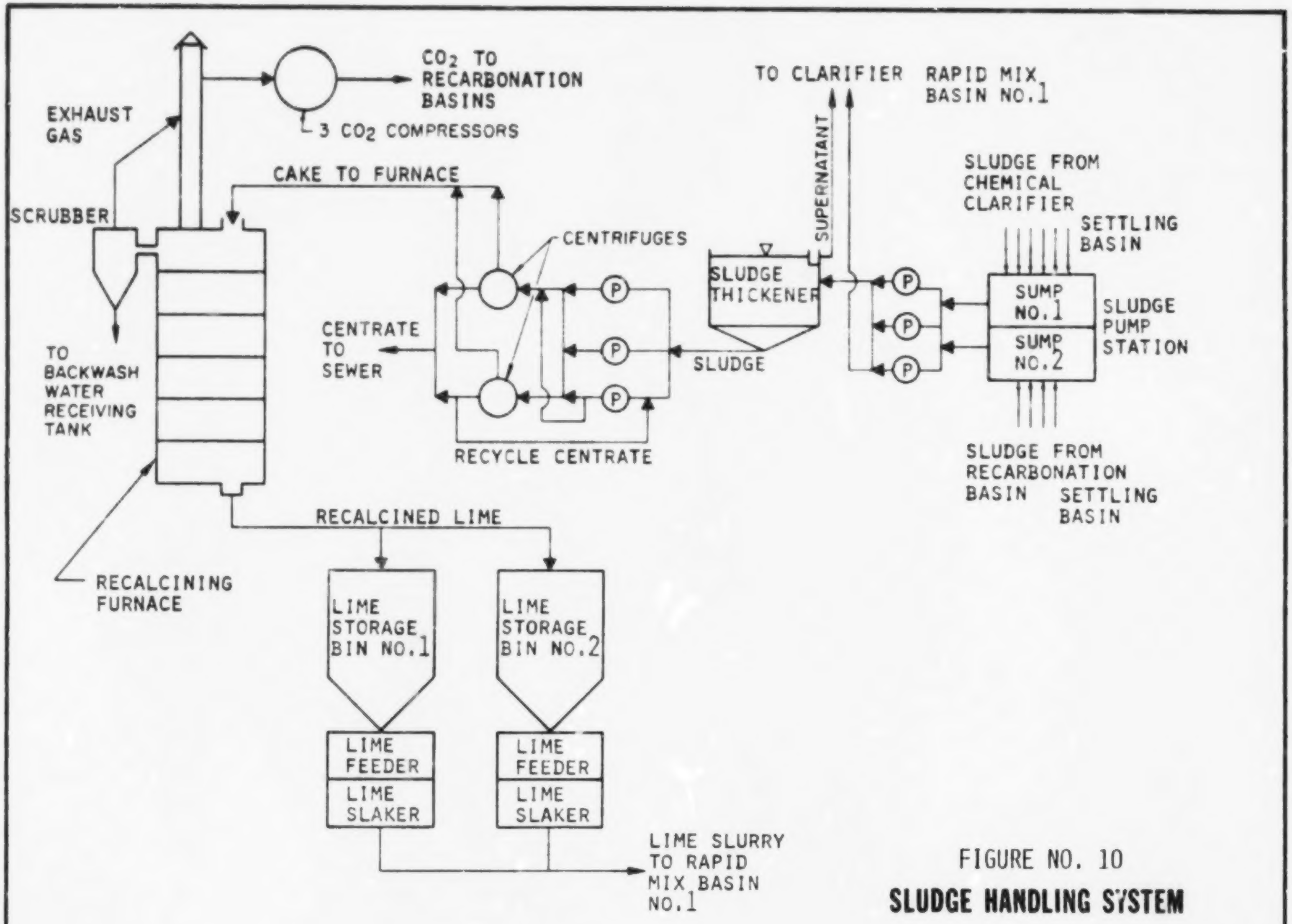
CO$_2$ TO RECARBONATION BASINS
3 CO$_2$ COMPRESSORS
EXHAUST GAS
SCRUBBER
TO BACKWASH WATER RECEIVING TANK
RECALCINING FURNACE
CAKE TO FURNACE
CENTRIFUGES
CENTRATE TO SEWER
RECYCLE CENTRATE
P
P
P
SLUDGE
SLUDGE THICKENER
SUPERNATANT
TO CLARIFIER
RAPID MIX BASIN NO.1
P
P
P
SUMP NO.1
SUMP NO.2
SLUDGE PUMP STATION
SLUDGE FROM CHEMICAL CLARIFIER
SETTLING BASIN
SLUDGE FROM RECARBONATION BASIN
SETTLING BASIN
RECALCINED LIME
LIME STORAGE BIN NO.1
LIME STORAGE BIN NO.2
LIME FEEDER
LIME SLAKER
LIME FEEDER
LIME SLAKER
LIME SLURRY TO RAPID MIX BASIN NO.1

FIGURE NO. 10

SLUDGE HANDLING SYSTEM

TABLE 5 CAPITAL AND ENGINEERING COSTS
15 mgd Wastewater Reclamation Facilities
Orange County Water District

Land		$ 200,000
Influent Pipeline & Pump Station		341,000
Clarification		756,000
Ammonia Stripping		2,834,000
Recarbonation		381,000
Filtration		861,000
Granular Carbon Treatment		3,027,000
Adsorption	$1,310,000	
Regeneration	452,000	
Building, control & other equipment	1,265,000	
Chlorination		361,000
Building & equipment	$ 79,000	
Contract basin	153,000	
Generator	129,000	
Sludge Treatment		1,688,000
Pump station	$ 94,000	
Thickener	47,000	
Centrifuges	115,000	
Furnace	565,000	
Building, controls, piping, electrical, & other equipment	867,000	
Blending and Storage Reservoir		235,000
Maintenance Building and Lab		240,000
TOTAL CAPITAL COSTS =		$10,924,000
Engineering		1,000,000
Design	$ 530,000	
Construction	470,000	
		$11,924,000

Note: Sitework, landscaping, electrical work and yard piping are charged to the individual treatment operations according to their percentage of total capital cost.

TABLE 6 ESTIMATED ANNUAL COST OF OPERATION AND MAINTENANCE
WATER FACTORY 21

15 MGD WASTEWATER RECLAMATION FACILITIES

Salaries Cost		$ 258,000
Maintenance Materials		40,000
Utilities		
Electricity	$473,000	
Natural gas	71,750	
Other	6,000	
Subtotal		$ 550,750
Chemicals		
Lime	$ 70,000	
Chlorine	10,000	
Activated Carbon	45,000	
Alum & Polymers	55,000	
Sodium Chloride	10,000	
		$ 190,000
Total Operations and Maintenance		$1,038,750

TABLE 7 TOTAL COSTS
15 mgd Wastewater Reclamation Facilities
Orange County Water District

	COST (c/thou. gal.)		
	Capital	Oper. & Maint.	Total
Influent pipeline & pump station	0.5	0.6	1.1
Clarification	1.1	2.4	3.5
Ammonia stripping	4.2	5.1	9.3
Recarbonation	0.6	1.1	1.7
Filtration	1.3	1.5	2.8
Carbon adsorption	4.5	3.7	8.2
Chlorination	0.5	1.0	1.5
Sludge treatment	2.5	4.6	6.1
Other	7.3	0.9	3.2
TOTAL	17.5	20.9	38.4

Note: Costs are based on the following assumptions:
1. Service life of facilities = 30 years;
2. Interest rate = 6%;
3. Facilities operate 330 days per year & produce 15 mgd.

DISCUSSION

QUESTION: Mr. Franklin D. Dryden, Sanitation District of Los Angeles County, Whittier, California. I want to ask if you had had any concern about air pollution problems from either your recalcination or your ammonium stripping process. Is there an APCD requirement you are meeting in either of these regards.

RESPONSE: Mr. Cline. When we first got the idea for the region from the Air Pollution Control Board and put out our plans, they gave us some rather stringent requirements on the off-gases from the furnaces. We have some sophisticated scrubbing units which we think are going to satisfy the requirement. For the ammonia towers, we have a five-fold safety factor--a dilution of about five. Consequently, we don't get any contamination from that source. We do get a very light obtundent odor in the morning.

COMMENT: Mr. Ongerth, California Department of Health, Berkeley, California. I think it would be helpful to clarify a couple points for the record. The chloride requirements, for example, are Water Quality Control requirements, not State Department of Health requirements, and some others fall in that category as well.

The other point is that the District is not in the clear with relation to domestic use of water that is drawn from this recharged water. The State Board of Health, in granting a permit for this operation, placed a provision that the kinds of questions that are going to be discussed at this conference had to be answered to indicate that we were on the side of safety before this water could be used in the domestic wells.

I am constantly confronted with questions around California from people who say, "Isn't Orange County recharging and using wastewater for domestic purposes?" And, of course, they are not even in operation yet. But beyond that, they will not be permitted to have this water reach domestic wells in ways that can be measured by the parameters that we may have to deal with in the future. I think it is important that this be understood.

RESPONSE: Mr. Cline. You can see that we are being monitored by the California Department of Health. Of course, we intend to cooperate. We don't have any choice as far as that goes.

WASTEWATER REUSE AS A WATER RESOURCE - THE DENVER EXPERIENCE

J. L. Ogilvie
Manager - Denver Water Department
144 West Colfax Avenue
Denver, Colorado 80202

ABSTRACT

Because of a unique water supply situation and after extensive planning, Denver and perhaps other communities are seriously considering reuse as an alternative for supplementing future supply. However, the distance between serious consideration and implementation is quite large, and much remains to be done to close the gap.

Denver's present supply comes from conventional tributary sources, a very limited groundwater supply, and extensive transmountain diversions. The potential of even this latter source will be insufficient within the forseeable future. Potable reuse appears to be the only major alternative to massive shortages.

Having performed the initial planning and research, it seems likely that reuse can be safely accomplished and accepted by the public. It is obvious, however, that the most difficult and costly research lies ahead. Water quality must be achieved. Adequate treatment will be required to guarantee a fail-safe system. Pollutants must be identified and removed. Ongoing studies will be required to guarantee safety prior to implementation. Progress will have to be continually assessed. Costs will have to be identified and compared with costs of treating conventional supplies.

One community cannot, and should not, solve these problems in isolation. We must recognize that the differences between indirect reuse and direct potable reuse are slight; that the former occurs today and that the latter will occur in the near future. Only through a coordinated national effort will research have the needed credance and yield answers in the few short years available.

Throughout the nation today -- in the press, by various scientific disciplines, among environmentalists and in the water utility industry -- there is an ongoing dialogue about water pollution and how to remove pollutants from water.

For years we have ignored the fact that human and industrial wastes pollute our natural water supplies in the first instance and, secondly, to remove contaminants placed there through the use of water by man.

When we discharge wastewater into a stream or river and allow it to be purified through the natural processes and dilution before it it is withdrawn for use again, we call it an indirect reuse.

However, when we take that same wastewater and route it directly through a treating process and immediately reintroduce it to another point of use, we say it is a direct reuse. It is this latter process, which is attracting the interest of municipal water utilities, that I will discuss with you today. I hope you will find the Denver experience, which has been in the experimental stage for several years and is on the planning board for implementation in the near future, of interest.

At the onset, I wish to encourage everyone in this field of water reuse not to be discouraged by criticism of going too slow. We are dealing with the health and well being of all of our people when we talk in terms of introducing a new factor into our drinking water supply. Therefore, it is absolutely mandatory that we proceed cautiously.

We have been in the water purification business a relatively short time, actually just a little over 100 years. Water purification by filtration dates from 1870, when an English-type slow sand filter was built at Poughkeepsie, N.Y. A municipal filtration system for bacterial purification of a water supply didn't come along until 1893 when Lawrence, Massachusetts completed a 2-3/4 acre bed and started filtering water from the Merrimack River. In 1908, in Jersey City, N.J., the water supply was chemically treated with chlorine compounds for drinking water -- another first.

Health problems caused by indirect reuse -- a city taking its water supply from a river at a point below the sewage outfall of another city -- are unfortunate. Adverse health effects by direct reuse of water are intolerable and unacceptable. The so-called "Magic Mile of Stream" to purify and dilute sewage, an old wives' tale, would have you believe that a stream moving faster than 2 mph purifies itself. There is nothing magical about a stretch of slow moving stream. It is aesthetically pleasing, but whether or not the water is being purified depends on many factors. However, comparison is usually made that, if there are dangers associated with indirect reuse, then there must be horrible consequences to direct reuse where Nature has not been involved. While not enough is known of the dangers of indirect reuse, logic would indicate that the more polluted the source, the greater the chance for health hazards.

Any indirect reuse of water should be accompanied with an ongoing program to find out the extent of pollution and methods of removing and/or treating the problems.

There is another less obvious distinction between direct and indirect reuses. Indirect reuse is an established practice. Direct reuse has never been tried on a large, continuing scale. Indirect reuse has developed over a long period of time through use of water treatment and pollution control plants which treat water as follows:

If it's sewage, secondary treatment.
If it's polluted surface water, coagulate it, settle it and filter it.
If it's pristine surface water, filter it.
If it's well water, chlorinate it.

If it should be determined that Nature is overloaded and health hazards do exist with this established system, the solutions will have to fit somewhere within the existing patterns of use and treatment.

With direct reuse, it's a whole new ballgame. New processes must be developed. And the public must be conditioned to accept the end product. No concrete has been poured or pipes laid in the ground. No plants have been built. No processes tested over long periods of time. It is not only possible but essential to answer the questions of safety before major facilities are built. What is required is man-made treatment which consistently does a better job than Nature in reducing pollutant levels. Direct reuse can be safer because the treatment, monitoring and control of product will be much more sophisticated. Reliability, redundancy, and fail-safe methods will be stressed. With an open awareness of the water source and acknowledgement of the possible dangers, planners, managers, and operators will be able to effectively provide a safe product.

The dangers of pollution in water sources have long been known. As a general rule, it has been assumed that selection of the "best available source" and the application of conventional treatment would guarantee safety. This philosophy is being questioned as identification techniques improve and as medical science discovers increasingly more obscure health effects from trace amounts of various pollutants. The concept of reuse evolved amid fears and doubts. Shortly after the unsuccessful 1957 Chanute, Kansas experience, concerns were voiced over reuse-related health effects. The concerns involved mainly biological contaminants. And agencies charged with protecting the public health started taking a closer look at possible dangers. A deluge of information and misinformation has appeared recently elaborating on the possibilities of any of the known chemical compounds being present in sewage. One argument states that a chemical could be undetectable and resistant to treatment and this mysterious "Agent X" could be concentrated through repeated reuse cycles causing insidious damage to an unsuspecting population. Labels of "toxic," "carcinogenic," "mutagenic," and "teratogenic," have been applied to this infamous, unknown chemical.

These concerns cannot be dismissed lightly. All of the possible dangers of reuse must be considered in designing a research program. Overreaction, however, and a fear of the unknown must not be allowed to cause abandonment of the reuse concept. The potential benefits in water supply are too great.

While some may challenge the concept of producing safe drinking water from sewage, most can envision a treatment train which would guarantee an acceptable product. Some might say (and historically have said) that conventional water and sewage treatment is adequate. Others might demand ten unit processes beyond distillation. The proper course of action, I believe, involves extensive and documented research to determine the extent of the dangers associated with direct reuse and the remedies. In this process, questions of cost, public acceptance, reliability and aesthetics must also be answered.

One of the most objective and enlightened approaches to direct reuse has been shown by the international group of experts assembled in 1971 and again last fall by the World Health Organization. Their report concluded that:

> ". . . Present-day technology is adequate if proper conditions prevail to treat most municipal wastewater to a degree that will render them safe for drinking and other domestic uses, by careful management, the application of appropriate treatment processes, and a rigorous programme (sic) of sophisticated surveillance, monitoring, and testing are absolutely essential if the public health is to be protected."

The report goes on to discuss the needed research and controls associated with such a program. The recommendations include provision that:

(1) Water quality standards appropriated to the reuse should be formulated and rigidly enforced.

(2) Full knowledge should be maintained of each water source, whether a natural body of water or wastewater, so that treatment may be adequately designed to allow for possible fluctuations in quality, account taken of potential health risks, and adequate safeguards taken to ensure the safety of workers and consumers.

(3) Laboratory facilities should be adequate to undertake the program of monitoring and testing appropriate to the proposed water use.

(4) Research should be conducted into the potential long-term health effects of trace materials and residues remaining after conventional water treatment. Research on this topic should include both physiological investigations on individuals known to have been using drinking water derived from polluted sources and toxicological studies on the waters themselves under laboratory conditions.

(5) Research should be conducted into improved methods of identifying, measuring, and monitoring chemical and microbial pollutants. Rapid identification of bacteria and viruses is required, and there is a need for a means of monitoring chemical pollutants by simple field tests.

Recent articles in technical media have concluded that these and other research efforts are needed. Most of the emphasis has been placed on the identification and inactivation of viruses and on the effects and identification of trace organic chemicals. In addition, questions of process reliability and public acceptance have also received attention. Recent estimates by the Environmental Protection Agency have placed the research cost at $50 to $150 million dollars.

The Denver Water Department is embarked on a direct reuse program. We have been supplying water to the Denver area for over half a century and streams in the area contribute only about 100,000 acre feet per year of supply which is insufficient to meet current continuing water needs. The Department has developed extensive transmountain diversions to augment this supply and we are now delivering over 250,000 acre feet each year in the Metropolitan area. Provision is made in some of our water appropriations, secured under Colorado Statues,for effective use and reuse of our previous water resource. Looking down the road 20 or 30 years we clearly see the time when direct reuse must be the source of continuing water supplies to meet people's needs. Denver began in the late 1960's to evaluate various methods for utilizing its sewage effluent and we are currently pursuing an aggressive program of research development to give us the capability of reusing our water safely. The Department's priorities are not with towing and melting icebergs or with trans-continental pipelines, but with a more realistic and viable source in Denver's own backyard.

From the beginning of the successive use program, public opinion has occupied a prominent place in Denver's thinking. No program can succeed without the approval of an informed public. It is obvious that all actions taken must be suppored by local and national attitudes which ultimately will be reflected in law.

The Denver Water Department commissioned an attitude and perception study in 1972 to test our citizens awareness of reuse. Results indicated that 65% of Denver residents were familiar with the reuse program. Also, the more familiar a person had been with the program, the more likely he was to approve of it. A question asked later in the survey, after showing each subject a reuse information card, produced a much higher approval of reuse than a similar question asked earlier. When the quantity of the reuse water was defined as equal to present supplies, acceptance jumped to 84%.

These results differ somewhat from studies conducted elsewhere. The differences may be attributable to the attitude of the interviewers or to Denver's extensive public information program. The important point is, though, that while a national public information program would be helpful, it is the attitude of Denver's citizens that is important to Denver. Public information programs will be continued and will remain primarily local functions.

Equally important as public acceptance is the necessity of meeting quality standards. The 1962 United States Public Health Service Drinking Water Standards list twenty chemical parameters, nine of which serve as absolute grounds for rejecting a supply as unsafe for human consumption. The World Health Organization Drinking Water Standards contain only a few more. Neither of these widely known and accepted standards lists more than a few synthetic organic compounds despite the fact that hundreds of such chemicals may find their way into municipal and industrial wastewater. The existing standards do not exhaust the list of potential inorganic toxicants that may be found in industrial wastes.

Conventional drinking water standards were originally based on the assumption that water for human consumption would generally be drawn from groundwater sources or from protected, uncontaminated surface water sources, and that the limited number of chemical parameters included were adequate. This assumption is rarely true for most surface supplies of today.

The 1971 recommendations of EPA's Technical Task Force on the Revision of the Drinking Water Standards states in part that, "the existing standards apply to a water supply that has been obtained from the most desirable source and are not intended for application to wastewater effluents, used directly as a raw water source." They were developed to be used in conjunction with a sanitary survey that would assure a relatively unpolluted source.

In all probability, more stringent standards will have to be developed for recycled water. Little has been done to date, however. Two alternatives are open for an agency considering potable reuse. One is to conduct in depth toxicological and epidemiological studies over a period of years to indicate any health problems and provide background criteria for workable standards. The other alternative is to adequately monitor wastewater and to remove the use increment between the raw water and sewage effluent. Thus the standards for renovation to a potable supply would be removal of the entire use increment. With monitoring sophistication, this would alleviate many questions concerning possible deleterious effects.

The latter approach has been chosen by the Denver Water Department and offers side benefits of considerable merit. First, "use increment removal" offers a hedge against future standards. There is no guessing at what standards might be set and no worry that a new standards might negate years of testing a process train. Second, the idea of "as good or better than what we're drinking" has a tremendous public relations benefit. Combining extensive analysis and "use increment" removal with biological (toxicological and epidemiological) studies as a guarantee on safety gives an enviable product -- it's not only safe, but it's as good as mountain water.

Sewage is polluted water. This fact does not take a great deal of verification. No one would take a drink from a sanitary sewer or bathe with secondary effluent. And yet, every glass of water consumed or bath taken from a metropolitan system contains water which has previously flushed a toilet. The difference, of course, is a matter of degree, of time, or proximity and, more importantly, of treatment.

Since sewage is vastly more polluted than most raw water sources, it is obvious that a much greater potential exists for health problems. The remedy, of course, is to apply the right combination of treatment -- natural and man-made -- to remove those contaminants posing a threat. This is no more than the goal of conventional water treatment, though requiring more effort. This all seems quite simple, but a problem arises in trying to identify the contaminants which pose a threat. With current technology we are not able to detect pollutants below certain concentrations and the health dangers of every constitutent of sewage are not known. Medical science may never be satisfied with its knowledge of such matters. For this reason the only logical approach for the higher order reuses is to remove everything which could possibly be of concern. In the case of potable reuse, this is use-increment removal.

Denver's use-increment removal program would depend heavily on treatment and monitoring to duplicate present potable water quality. This level has been shown safe through years of use. Medical health effect studies would assume a secondary or fail-safe role. Toxicological examination would have to accompany the program as a safeguard though direct reliance on the results would not be necessary. Epidemilogic evaluation, while needed nationally, would have little direct bearing on such a program since there would be no better quality water with which to compare.

The practice of advanced wastewater treatment has developed from rudimentary beginnings to its current status as a proven tool in man's fight against pollution. As with any new technology, the development of AWT is continuing and new advances will be made. The state of the art is at such a point today, however, that reliable processes can be linked to produce whatever quality water is desired. The higher the quality, the more the cost, of course.

The only demonstrations to date of potable reuse have either been accidents or have had far different goals than those presented here. The space industry experience has involved only short-term use and the South-West Africa experience has evolved with less regulation and less citizen involvement than expected in Denver. The Denver Water Department's goals of absolute safety and reliability combined with duplication of original quality necessitate a plant-scale demonstration prior to full scale implementation. Economics dictate that this plant be smaller than a 100 MGD capacity of a full size plant. Balancing all factors, we conclude a demonstration plant of one MGD is the most desirable size. This plant operating for a number of years would yield design criteria for up to 100 MGD of full size construction and would produce the water needed for extensive quality and health testing.

Data from a one MGD plant would allow further future designs to maximize reliability without spending money for excess redundancy. Therefore, a demonstration plant should be designed with sufficient flexibility so that optimums can be found. On the other hand, there is no point in installing extra processes not anticipated to be needed since resulting product water data would be misleading. Instead, side streams of less than one MGD would be included to evaluate processes which might eventually prove better than those originally installed.

Denver's program of research involves pilot plant operations, sponsored research at the University of Colorado, cooperation with EPA, use of nationally known consultants, public information programs and related functions such as project direction and planning. Major additional elements of the programs include actual construction of a 1 MGD demonstration plant producing potable water. Extensive quality monitoring and toxicological studies on the water will be pursued for several years while the product water is being used for non-potable purposes.

In December, 1974, we assembled a panel of advanced waste treatment experts in Denver to advise the Department and its consultants, on process of selection. The consultants are presently conducting a conceptual design study on the proposed demonstration plant. The plant is expected to be on-line in 1978 and will operate as long as is necessary to determine economic feasibility, absolute safety and public acceptance of what we are doing.

Denver's efforts toward direct potable reuse are the results of circumstances not uncommon in other areas. As a result, the questions to be answered here will contribute to the national knowledge of pollution and water supplies, but will not solve all the problems facing the industry because our program will be influenced by local conditions. Little or no spinoff is expected in the area of indirect reuse health effects, for instance. In addition, it is inconceivable to imagine that Denver, working alone, can perfect monitoring techniques adequate to guarantee safety in all other areas.

In this new found era of environmental enlightenment, the terminology of "space ship earth" has been used many times to help us relate to some of our global-environmental crises. It is significant to note that recycling water for direct potable reuse was a primary goal of the National Aeronautical Space Administration. I submit that direct potable reuse should be a primary goal of the World Health Organization and the U. S. Environmental Protection Agency.

In summary, then, to achieve this goal it seems to me our priorities should be:

1. Recognition and acknowledgement of the need for a national research program on direct potable water reuse.

2. Directing a major part of this national research to health questions to determine if direct and indirect reuse of water has any possible detrimental effects on users.

3. Establishing a significant budget to carry on this program to assure reliability and public acceptance.

4. Developing improved laboratory analytical equipment and procedures capable of measuring trace amounts of contaminants and rapid identification of bacterial and virus particles.

Provisions in the 1974 Safe Drinking Act address this need. Sections in the Act provide research monies in the reclamation field. But the water industry must continue to challenge federal and state agencies to provide sufficient funds so that these objectives can be achieved.

Simply put, money right now is the name of the game. And the current federal budget of $400,000 is grossly inadequate. It should be in the range of $5 to $10 million annually. Only through substantial and coordinated total efforts, will our reuse research endeavors of the 70's and 80's yield the answers to assist in the solution of present and future water resources problems.

DISCUSSION

QUESTION: Mr. Ongerth, California Department of Health, Berkeley, California. What is your prediction of when Denver might be starting with the final reuse?

RESPONSE: Mr. Ogilvie. Well, as we see it now, we are going to have to move to the direct reuse of water by the 1980's or early 1990's. That is quite a ways down the road, but when you consider the research, and the fail/safe procedures that have to be established, it will go very rapidly.

QUESTION: Mr. Ongerth, California Department of Health, Berkeley, California. Then this is your prediction of when Denver will be making direct potable reuse?

RESPONSE: Mr. Ogilvie. Yes, sir.

QUESTION: Mr. Gallowin, National Bureau of Standards, Washington, D.C. Can you give us an indication of projected costs involved in direct reuse?

RESPONSE: Mr. Ogilvie. Yes. Our reuse program will be directed toward taking those waters which we can recycle, those we actually own and which we could use as many times as possible, and producing this potable grade water. Then we will initiate a program of recycling it and diluting it into our normal water supply such that no particular area of the city will initially have one hundred percent of the reprocessed or reuse water. Down the road in later years, when reuse is more of an accepted pattern, this may not be necessary. But under the circumstances, we think it will have to be diluted back into our present system.

QUESTION: Mr. Gallowin, National Bureau of Standards, Washington, D.C. At what cost? Are we speaking of fifty cents per thousand gallons or ten dollars per thousand gallons?

RESPONSE: Mr. Ogilvie. I think our costs will run in the neighborhood of maybe seventy-five cents per thousand gallons.

WASTEWATER TREATMENT TECHNOLOGY FOR POTABLE REUSE*

R. B. Dean and J. J. Convery
Science Advisor and Director
Advanced Waste Treatment Research Laboratory
Environmental Protection Agency
Cincinnati, Ohio 45268

ABSTRACT

Technologies are available today to produce reusable water of potable quality from municipal wastewater. The choice of a system depends on the quality and quantity of available dilution water, facilities available for disposal of waste products, and the scale of the operation. Long-term, reliable operation of waste treatment plants producing water for reuse has been demonstrated in situations where there is a need for the water or where strong regulations control discharge parameters. Leading unit operations are discussed in terms of their capability to reliably remove specific pollutants. Adjuncts that will improve reliability include instrumentation, surge capacity, and provision for disposal or reprocessing of substandard product. Specific case studies illustrating performance are presented.

INTRODUCTION

Wastewater treatment technology can potentially produce a renovated effluent that meets all objective drinking water standards. Health effects research aimed at revising current standards or developing new ones should apply to all water sources and should not differentiate between traditional supplies and renovated effluents. The preceding statements are intended to stimulate discussion and should be considered by all of the workshops at this conference on reuse.

The treatment received by municipal wastewater before its reuse as part of a potable water source has varied from minimal primary treatment, or even less, to the sophisticated chain of treatment at Windhoek, where a dilution ratio of less than six parts of surface water to one part of reclaimed wastewater has been used (1). All potable reuse systems employed to date have had two aspects in common: time and dilution. The more time and the more dilution that is available, the less treatment has been deemed necessary before a municipal effluent is reused as a potable water supply.

So much for history. Primary treatment is no longer sufficient for discharge, even to rivers that are not used as a drinking water source, and there is some new evidence that conventional water treatment may not be removing enough pollutants from some supplies (2). Better water and wastewater treatment technology will be required as our knowledge of the occurrence and effect of specific contaminants increases. The purpose of this paper is to review the specific capabilities of current wastewater treatment technology.

STANDARDS TO BE MET

The new standards for potable water have not yet been published by the EPA. There are several sets of standards and recommendations in the literature. These include the Public Health Service Drinking Water Standards of 1962 (3), the WHO recommendations of 1964 (4), the AWWA goals of 1966 (5), the Green Book of 1968 (6), and the Blue Book recommendations of 1972 (7). For public drinking water supplies, the Blue Book recommendations by the Committee on Water Quality Criteria of the National Academy of Sciences, National Academy of Engineering, probably represent the best published approximation to forthcoming standards. These recommendations are for raw water quality for public supplies and are intended to assure that the water will be potable - for surface water with defined treatment; (flocculation, sedimentation, rapid sand filtration, and disinfection)- and for groundwater with no treatment. The recommendations already incorporate substantial factors of safety.

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Table 1 compares Blue Book recommendations for very toxic elements with the average product water from advanced waste treatment pilot plants at Dallas (8) for 8 months and Denver (9) for 8 months. In both plants, biological treatment was followed by lime precipitation to a pH greater than 11. The clarified water was filtered and passed through granular activated carbon. Table 2 makes the same comparison for less toxic elements; some of them are limited because they cause taste or color problems in water supplies. Table 3 lists limits for selected organic compounds in micrograms per liter and compares them with concentrations in the Dallas effluent (10). Only a few of the pesticides tabulated in the Blue Book are listed. Robeck, et al.,(11) showed that activated carbon columns were effective for removing pesticides even when taste and odor broke through. The more toxic pesticides are being limited to authorized applicators for special situations, and their concentration in the environment should be decreasing. In general, the recommended levels are less than a fifth of the level considered safe by the Blue Book committee.

The nonspecific parameters, MBAS and CCE, are compared with South Lake Tahoe (12) and Pomona (13) effluents. Tahoe used a scheme similar to that of Dallas and Denver; Pomona fed unfiltered activated sludge effluent directly to the carbon columns for a 4-year period. Table 4 compares salts and nutrients with the effluents of the Central Contra Costa Sanitary District (CCCSD) ATTF plant (14). This plant treated 1.5 mgd (6000 m^3/day) of residential wastewater with lime, followed by biological nitrification and denitrification in a 3-month pilot study for a plant to reclaim water for industrial use.

TABLE 1. VERY TOXIC ELEMENTS mg/l

	Std.	DL	DS
Mercury	.002	.0001	
Cadmium	.01	.008	.002
Selenium	.01	.001	-
Chromium	.05	.009	.006
Lead	.05	.045	.027

TABLE 2. LIMITED ELEMENTS mg/l

	Std.	DL	DS
Manganese	0.05	.006	.05
Arsenic	0.1	.007	-
Iron	0.3	.05	.16
Barium	1.0	.10	-
Copper	1.0	.04	.08
Zinc	5.0	.03	.13

TABLE 3. ORGANICS μg/l

	Std.	DL
Aldrin	1.0	.007
DDT-Total	50	.006
Diazinon	100	.003
2, 4-D-Total	20	.1
MBAS	500	150(T)
CCE	300	26(P)

TABLE 4. SALTS AND NUTRIENTS mg/l

	Std.	CC
Chloride	250	-
Sulfate	250	-
Phosphate	-	1.0
Ammonia N	0.5	0.4
Nitrate N	10.0	0.8

References: Std, Blue Book (7); DL, Dallas metals (8), pesticides (10), CC, CCCSD (14), DS, Denver (9), T, Tahoe (12), P, Pomona (13).

Based on available information, there will be little difficulty in meeting the published recommendations by applying proven advanced waste treatment technology to municipal wastewater. However, source control may be required to prohibit excessive industrial discharges of highly toxic wastes such as mercury, selenium, and some pesticides. In general, biological treatment, chemical precipitation, and carbon adsorption can remove the listed contaminants, with the exception of salts. Dilution with water of low TDS, either from fresh-water supplies or desalted brackish water, is currently the most economical way to keep salts within limits.

TECHNOLOGY FOR RELIABILITY

Reliability, like any other aspect of treatment, costs money. One can expect only as much reliability as is required or paid for. The Community Water Supply Study of 1969 (15) showed that the reliability of plants increased from 76% in small plants to 100% in the largest plants, as measured by the percent that met mandatory limits. However, the percent that met recommended limits was almost independent of plant size and averaged only 75%. Obviously, a large plant is better equipped than a small plant and can more easily meet requirements, but even the largest plants had no incentive to meet recommendations.

When a monetary value is set on the product water for reuse, then reliability can become very good. Whittier Narrows in the Los Angeles County Sanitation Districts has sold more water for indirect potable reuse than any other plant. The water is sold at the same price as Colorado River water and is used with the river water to recharge undergound aquifers (16). This activated sludge plant has operated from 1962 through 1974 without interruption from internal causes, but it has been shut down once or twice because of industrial toxicants or flood waters. The plant has paid off its construction costs out of net operating revenues in less than half of the projected time. The high level of performance owes much to the dedication of the operating management, but it is certainly reinforced by the fact that the plant loses money whenever it is not meeting specifications. Figures 1, 2, and 3, based on data supplied by John D. Parkhurst (17), show the fraction of the time in 1974 that

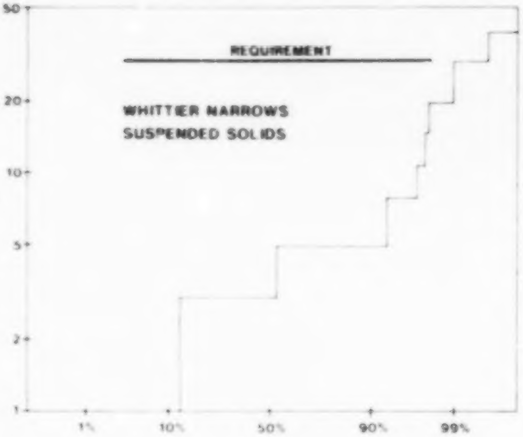

Figure 1. Suspended Solids at Whittier Narrows Effluent

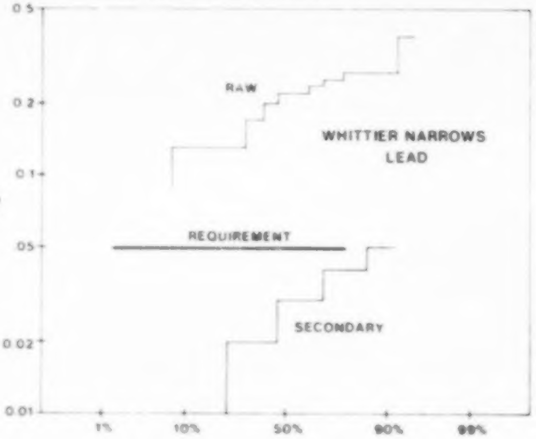

Figure 2. Lead in Raw and Secondary Effluent at Whittier Narrows

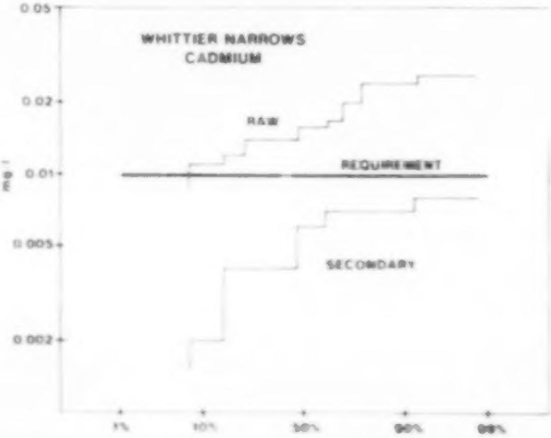

Figure 3. Cadmium in Raw & Secondary Effluent at Whittier Narrows

each parameter was less than the plotted value for cadmium, lead, and suspended solids. Concentrations of the unfiltered effluent are shown on a logarithmic scale. The California Drinking Water Requirements are shown for the metals, and the EPA secondary treatment requirement for the suspended solids.

In the case of South Lake Tahoe (12), the District is prohibited from discharging any wastes in the Basin and must meet strict requirements for export to its own reservoir in the adjacent drainage basin. Figures 4, 5, and 6 show the fraction of days the selected parameters were less than the values shown for turbidity, COD, and coliform. These data cover the period from September 1968 to December 1974 and are based on monthly reports showing daily performance for over 2,000 days. Suspended solids were uniformly below detectable limits (1.0 mg/l). Requirements for export are shown as stepped lines passing through the points specified by the Lahontan Regional Water Quality Control Board.

The overall reliability is unprecedented in waste or water treatment plants and would be considered excellent in the chemical industry for a factory having the same capital cost. The total cost of operation, adjusted to operation at design capacity, is approximately twice the cost of operation of a conventional secondary treatment plant that is required to deliver only 30 mg/l BOD, 30 mg/l SS, and 200 MPN water with no limits on phosphates, MBAS, or COD (18). Examination of the raw data suggests that the plant quality has crept closer to the required limits as the years have gone by.

One of the reasons for the excellent reliability of the Tahoe plant is the availability of large storage volumes that can be used to equalize flow and reprocess any substandard product. When a manhole cover near a creek bottom was pulled off in December 1973, flood waters delivered more than twice the design flow for 2 days. An excess 24 million gallons (100,000 m^3), which is more than 3 times the daily design flow, was stored and worked off over a whole month without exceeding the required limits at any time.

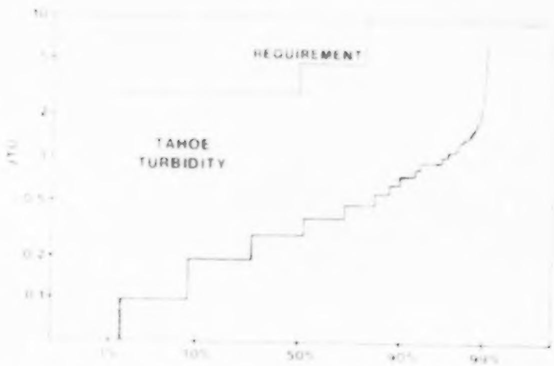

Figure 4. Turbidity in Tahoe Effluent

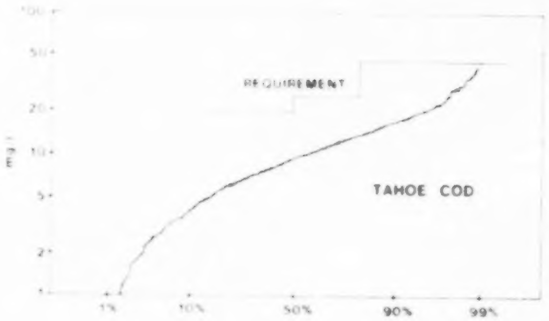

Figure 5. COD in Tahoe Effluent

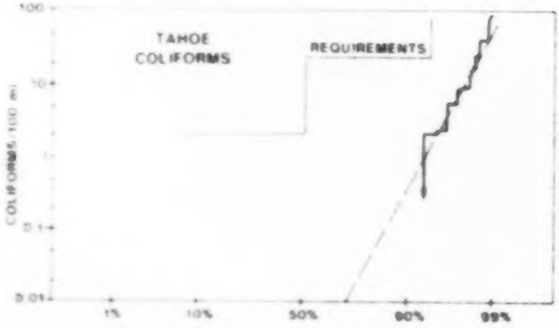

Figure 6. Coliforms in Tahoe Effluent

An alternative to storage is provision to bypass substandard water to a disposal site. At Whittier Narrows, wastewater is drawn from a large trunk sewer and sludge is returned to the same sewer along with any effluent that might not meet specifications. Because treatment is expensive, specifications are carefully met, and very little treated water is wasted.

In addition to the aforementioned facilities that will promote reliable operation (namely storage or bypass capacity and the support functions of economic incentive, enforced legal restraints and dedicated personnel), there are a number of engineering design features that will improve reliability. The EPA has recently published a Technical Bulletin on design criteria for component reliability (19) which is described in a recent article (20). The new criteria would have prevented or mitigated 91% of historical failures in 21 plants studied. The cost increase to meet the new criteria is estimated to be from 1 to 7% of new construction costs. Consistent application of reliability design features, not only in the components listed in the bulletin but also in the biological and chemical processes used, will substantially improve the admittedly unsatisfactory operation of many municipal wastewater treatment plants in the past. A combination of good design and strong incentive can supply the required degree of reliability for reuse purposes.

In the following section, various unit processes will be examined from the point of view of performance and reliability, since without reliability, potable reuse becomes unthinkable.

UNIT OPERATIONS AND SYSTEM OPTIONS

Several single-step phase change purification processes, including distillation, freezing, and solvent extraction, have been suggested for wastewater treatment. Despite the apparent simplicity of a single process that would separate pure water from all pollutants, it has proven to be less expensive and more reliable to employ a series of processes, each designed to remove one or more categories of pollutants. Each process can be adjusted to the peculiarities of the wastewater, and the series can provide multiple barriers to biological pollutants such as viruses. Limited full-scale experience is currently available on the performance of complete wastewater renovation systems specifically designed to produce potable quality water. However, abundant information is available on the performance, cost, and reliability of candidate processes that could be incorporated into wastewater renovation systems.

Unit Operations

Systems that are suitable for utilization in wastewater renovation systems include biological or chemical oxidation, chemical precipitation, sedimentation, filtration, adsorption, and disinfection. The choice of process and the order in which the processes are used varies, and any one of them may be employed more than once in the treatment sequence.

Primary sedimentation is the lowest cost process for removing the bulk of the solid pollutants in wastewater. A primary clarifier can reduce the cost of subsequent biological treatment and is cost effective in larger plants. Chemical precipitation with lime, iron salts, or alum in the primay can further reduce the load on the biological system. Lime treatment to a high pH removes most of the phosphates and more than half of all other major pollutants, including soluble TOC and prepares the effluent for reliable biological treatment. Lime clarification followed by biological nitrification was chosen at CCCSD (14) as the lowest cost way to meet local requirements for reuse or discharge to San Francisco Bay. Other studies have shown significant removals of pathogens (21) and heavy metals (22, 23) when the primary tank is limed to a pH of 11 or more. Lime treatment is easy to control by pH; the volumetric dosage is proportional to flow but is relatively independent of fluctuations in water quality entering the plant. The sludge produced can be processed for disposal or reuse without digestion (24).

Aerobic biological treatment in suspended growth reactors (activated sludge, aerated lagoons) or fixed film reactors (trickling filters, rotating biological disks) is the lowest cost method for removing most small soluble organic molecules. Biological processes can also be used to oxidize ammonia to nitrates (25,26) as well as to reduce the nitrate to nitrogen gas. A well-managed biological plant is capable of handling normal diurnal fluctuations in load but is limited hydraulically by the capacity of the clarifiers. Modifications have been developed that permit biological treatment to adjust to very wide fluctuations in load, provided that the fluctuations are recognized as they enter the plant (27). Instrumental sensing and control of dissolved oxygen in activated sludge can reduce aeration costs and increase performance (28).

Tertiary treatment with chemicals is even more effective than primary flocculation and forms the basis for most AWT systems designed to produce reusable water (Tahoe, Dallas, Boulder). For maximum performance, it is necessary to filter the clarified effluent in a multi-media filter, using an appropriate flocculant to remove colloidal precipitates. At Ely, Minnesota almost complete removal of phosphates is necessary to protect Shagawa Lake from excessive algal growth (29). The Ely plant uses an existing trickling filter plant, which is followed by two-stage lime clarification at pH 12 and 9.6, respectively, addition of ferric chloride and sulfuric acid to pH 7.5, and multi-media filtration with supplemental alum feed and chlorination. From March 1973 through August 1974, the monthly averages of total phosphate in the effluent varied between 0.021 mg/l and 0.077 mg/l, with an average of 0.043 mg/l. This demonstration project has shown that an exceptional quality product can be produced by providing tertiary treatment to an existing facility that is grossly overloaded.

Adsorption on carbon is a reliable process for removing nonpolar and surface-active organic molecules from solution (30). Regeneration at about 950°C destroys all the adsorbed organics, converting some of them to more activated carbon. Bacteria growing on partly exhausted static carbon beds appear to liberate substances such as amino acids, which are difficult to retain on carbon. New operating techniques may have to be developed if it is demonstrated that the leakage of this organic matter significantly degrades water quality. The substances produced by bacterial action on carbon that is used to treat water supplies will be similar to those produced in the treatment of wastewater. When limits are set for organic matter in drinking water, it will be possible to decide on the advanced waste treatment system that will meet these standards. Present limits are based on extracts of test carbon columns, CCE, and may have little toxic significance (31).

The stepwise removal of metals by chemical precipitation, filtration, and adsorption on carbon has been followed by Murayama, et al., (23) in a physical-chemical system using lime or iron salts as flocculants. In such a system, there is substantial removal of organic matter by bacterial action in the carbon columns. In these pilot plant studies, each successive step in the system removed a significant part of the toxic metals. Cadmium was removed principally by chemical precipitation and settling, with filtration and carbon adsorption each contributing only a small additional removal. Chromium, however, was poorly precipitated by iron salts or lime, but reduction on the carbon column and precipitation as the trivalent hydroxide increased the overall removals up to 99%.

Disinfection is a necessary final step in any water reuse system. Adequate disinfection requires previous removal of all suspended matter, whether the source be river water or municipal effluent (32). Violation of the turbidity standard alone should be justification for rejecting recycled water from any source, no matter what method is used for disinfection. The AWWA goal is 0.1 Jackson Turbidity Units (JTU) (5). The possible formation of chlorinated organics when water containing organic matter is chlorinated (33) suggests that chlorination should be used only as a last step, after the water has been freed from dissolved and suspended organic matter. Removal of turbidity and soluble organic matter is also desirable and perhaps mandatory before final disinfection with any other agent such as ozone or ultraviolet light. To reduce the chance of pathogens being discharged through the treatment system, lime clarification should be considered. Lime clarification in the primary is an alternate to prechlorination. Though lime does not sterilize water, it does significantly reduce both pathogens and indicator organisms (21). White (34) has pointed out that a given chlorine treatment reduces the bacterial count by a calculable factor, for example, 3,000-fold. If the previous treatment has reduced bacterial counts below 3,000, then terminal disinfection will reliably destroy the remaining organisms. There is no evidence that water that is free from turbidity and has retained a free chlorine residual of 1 mg/l for at least one hour can contain infective viruses or enteric bacteria. All the available evidence indicates that such water will be biologically safe regardless of whether it came from a wastewater plant, a polluted river, or a protected water source. A fail-safe procedure would be to hold the water in batches for one hour and monitor free chlorine, turbidity, and organic matter before releasing each batch. Water that failed to meet specifications would be reprocessed. Automatic instruments are available for all of the suggested quality assurance tests.

Nitrogen in the form of ammonia must be reduced below 0.5 mg/l to meet drinking water standards. If nitrogen compounds are present as nitrates, up to 10 mg/l N is acceptable. Biologically treated wastewater usually contains less than 20 mg/l of N, either as ammonia or as nitrate. Conversion of nitrogen from ammonia to nitrate is a biological process that is well understood (25, 26). Nitrates can be converted to nitrogen gas by further biological treatment when it is necessary to meet effluent requirements as at CCCSD (14). If 50% dilution water is available, nitrogen can be most economically controlled by conversion to nitrates with destruction of ammonia residues by breakpoint chlorination (26). Removal of all nitrogen by breakpoint chlorination is probably unsuitable because it results in as much as 200 mg/l of additional chloride and over 300 ppm of additional TDS in the product water. Ammonia can also be removed by air stripping in warm climates (35) or by adsorption on selective ion exchange minerals (36), as is being proposed at Occoquan.

Organic matter is removable by a combination of biological oxidation, flocculation, and adsorption. Traces of low-molecular-weight compounds, including some chlorinated hydrocarbons, may not be captured by any of these processes. Their presence in surface water supplies has very recently been documented (33), but their toxicological significance is, at present, unknown. Removal methods applicable to water and wastewater treatment plants will have to be developed.

In many situations, desalting of wastewater will not be necessary. If the makeup or dilution water supply has a TDS of less than 150 mg/l and the normal municipal increment is 350 mg/l, then half of the water supply can be reused effluent at 850 mg/l without exceeding the PHS limits of 500 mg/l in the blend. If the makeup water supply has a higher TDS, or if more than 50% reuse is necessary, then it may be more effective to desalt the makeup water rather than the recycled water. This is the method chosen by Orange County. The makeup water will be distilled sea water (35).

Distillation has been considered as a complete process for purifying wastewater using essentially the same equipment that is used to desalt sea water. However, distillation is a very poor method to separate volatile pollutants such as ammonia and numerous organic compounds from water (37). Furthermore, scale and baked-on organic residues will quickly foul heat-exchange surfaces. Cost estimates have repeatedly shown that advanced waste treatment systems for removing nutrients and organic matter are less expensive than distillation. Distillation, however, is currently being studied to remove all the inorganic matter (represented as TDS) from water. In fact, distilled water should have some salts returned before it will be acceptable to most water utilities.

Other desalting processes include reverse osmosis and electrodialysis. Membranes used in these processes are easily fouled by the components of wastewater so that extensive pretreatment will be required. At present, reverse osmosis is being considered for small mobile wastewater reclamation systems (38). Removal of dissolved salts from water by any method is an expensive operation that is complicated by the fact that the salts that have been removed must be disposed of as a brine. Disposal to the open ocean is the only low-cost method (39). Natural solar evaporation is the next choice, but it is possible only in arid areas (40).

CONCLUSIONS

1. Wastewater treatment performance data is not available for all of the parameters included in existing drinking water standards.

2. Information that is available indicates that wastewater treatment technology is capable of meeting all the standards that have been measured.

3. Full-scale wastewater treatment facilities can be operated reliably over long periods of time.

4. Long-term reliability testing of a full-scale facility specifically designed to produce potable quality water is needed.

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DISCUSSION

QUESTION: **Ms. Hend Gorchev, EPA, Washington, D.C.** John, have you measured the influent concentration for carbon-chloroform extracts of any of the organics?

RESPONSE: **Mr. Convery.** We do not have directly comparable data on CCE before carbon treatment because the secondary effluent is not filtered before being fed to the carbon columns at Pomona. The CCE apparatus would not work on unfiltered wastewater.

QUESTION: **Mr. Gorden G. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio.** I find it very difficult, John, to read that. Is that a point Hend? That 26 didn't show. Is that what is making you wonder on the CCE?

RESPONSE: **Ms. Hend Gorchev, EPA, Washington, D.C.** Yes.

RESPONSE: Mr. Robeck. Water Supply Research Laboratory, Cincinnati, Ohio. That seems highly unlikely with a COD level of ten.

RESPONSE: Mr English, EPA, Cincinnati, Ohio. I was responsible for those data and they are accurate. They have been published in a paper that I wrote in cooperation with Frank Dryden from L.A. County Sanitation District. (Reference 13).

RESPONSE: Mr. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. Well, we are going to have to tell the waterworks people that they can go ahead and put carbon in there.

RESPONSE: Mr. English, EPA, Cincinnati, Ohio. That's probably an average.

RESPONSE: Mr. Convery. It's an average value.

RESPONSE: Mr. English, EPA, Cincinnati, Ohio. I've got a group of those same levels that you are welcome to look at.

QUESTION: Mr. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. Average for three weeks or three months?

RESPONSE: Mr. Convery. Four years.

RESPONSE: Mr. English, EPA, Cincinnati, Ohio. And we actually took those samples just prior to regenerating the carbon. We could have cheated and taken those when we put a fresh batch of carbon in. But we took those just prior to taking off one of those carbon batches.

QUESTION: Mr. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. What is the cycle then for regenerating?

RESPONSE: Mr. Convery. It was at a COD breakthrough of 14 or 10.

RESPONSE: Mr. English, EPA, Cincinnati, Ohio. A COD breakthrough of 12. This is total COD. We averaged about 8 to 10 over the run.

QUESTION: Mr. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. So the cycle varies. What you are saying is that you are not going to give me a figure.

QUESTION: Mr. English, EPA, Cincinnati, Ohio. What do you mean? Do you mean as far as days of operation?

RESPONSE: Mr. Robeck, Water Supply Research Laboartory, Cincinnati, Ohio. Yes.

RESPONSE: Mr. English, EPA, Cincinnati, Ohio. About seventy-five days. We had to regenerate about twenty-five percent of the carbon every seventy-five days, and we measured the carbon-chloroform extract at the end of that seventy-five-day cycle.

QUESTION: Mr. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. What method were you using for measuring the CCE?

RESPONSE: Mr. English, EPA, Cincinnati, Ohio. We were actually using the standard three-inch diameter system with the low flow of 120 ml. a minute. That may be that data, John. I am not sure. But even that one met the standard of .2 mg per liter at the low flow.

RESPONSE: Mr. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. I wanted to stress that the Blue Book had it at .3 mg/ℓ or what you call 300 µg/ℓ, on the basis of a certain analytical procedure. And the drinking water standards of 1972 had it at 200 µg/ℓ and the new one is going to be 700 µg/ℓ. They are all different because of different analytical methods. So we want to be sure that we are collecting the data and comparing them with those same methods each time.

We have had a lot of difficulty in getting the CCE down that low for much more than four or five weeks on, say, ordinary Ohio River water. So there is something here that doesn't meet the eye. We will have to talk about it when we get back home.

QUESTION; Mr. John T. Cookson, University of Maryland, College Park, Maryland. You mentioned that it might be difficult for a turbidity of one to be obtained?

RESPONSE: Mr. Convery. One-tenth. The AWWA said one-tenth.

RESPONSE: Mr. Cookson, University of Maryland, College Park, Maryland. O.K.

RESPONSE: Mr. Convery. With one, I don't see any problem. One-tenth can be very difficult.

RESPONSE: Mr. Cookson, University of Maryland, College Park, Maryland. O.K. I misunderstood you.

RESPONSE: Mr. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. I think it's going to be one-tenth.

RESPONSE: Mr. Convery. Ten percent of the time.

RESPONSE: Mr. Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. If we can do it in Duluth, you can do it there.

RESPONSE: Mr. Robert Dean, AWTRL, US-EPA, Cincinnati, Ohio. I co-authored on this paper. Remember Tahoe wasn't asked to do one-tenth. You shouldn't say that the system isn't capable of meeting one-tenth when you have never tried.

RESPONSE: Mr. Convery. That's a good point. But that's still a tough standard.

TREATMENT RELIABILITY AND EFFLUENT QUALITY CONTROL FOR POTABLE REUSE

H. J. Ongerth
State Sanitary Engineer
J. Crook, Ph.D.
Sanitary Engineering Associate
California State Department of Health
2151 Berkeley Way
Berkeley, California 94704

ABSTRACT

Effluent quality control must be founded upon effluent quality standards. Effluent quality standards, which have not yet been promulgated, must be considerably more comprehensive than the existing or proposed Federal Drinking Water Standards. Present knowledge is limited in several areas, including the identification, monitoring, and health effects of chemical contaminants. Treatment plant effluent reliability must be of the highest order for potable reuse. Experience records on plant performance and reliability and proposals for high order reliability are presented.

INTRODUCTION

It is startling to read in the printed program that "The objective of the workshop is to define and establish priorities for research needed to develop confidence in the reuse of wastewater for potable purposes." (Emphasis added.) In my judgment the workshop objective should be "to define and establish priorities for research needed to determine if reuse for potable purposes is possible, to determine if it is desirable and cost-effective and (if established to be possible, desirable and cost-effective), how to design to assure fail-safe reliability and assured quality control."

Renovated wastewater is a poor source for domestic water supply. Every use of renovated wastewater may impose some public health risks. These will scale from very low order, almost insignificant, to the high level of risk involved in direct reuse for potable purposes. In order that the risk from reuse for potable purposes be kept to an acceptable level, it is essential that such reuse schemes have high orders of reliability and quality control. Risk analysis techniques should be applied.

This discussion is dependent upon the circumstances of delivery of wastewater to the point of intake of a potable water system. Domestic water supply intakes are downstream on river systems from waste discharges. Time and dilution may be significant factors. This practice is often referred to as "indirect" reuse. In other situations, groundwaters may contain wastewater effluents reaching the aquifers either by percolation from surface spreading or near surface disposal or by direct injection into an aquifer. This also constitutes an "indirect" reuse. With relation to groundwaters, time, dilution and change in constituents and constituent concentrations by contact with the soil systems may significantly alter the wastewater before it reaches a water supply intake. With both surface and groundwaters, in the limit, wastewater may reach a water supply intake essentially unchanged by dilution or other factors. Up to the present time engineered systems have carefully avoided a "direct" interrelationship of waste discharge to water supply intake. The following material is presented without attempting to couple hazard with particular circumstances of disposal.

RELIABILITY

The California Department of Health conducted several studies of reclamation and sewage treatment plant operations in the late 1960's. These studies revealed that during the year preceding the studies, 40-60% of the plants experienced serious equipment breakdowns, 30% bypassed untreated sewage, over 50% had power outages, 60-70% had no emergency power source, and 70% had no alarm system. A 1970 study of 42 wastewater reclamation plants utilizing gas chlorination systems determined that only 15 (36%) of the plants had the three basic features essential to assure an uninterrupted supply of chlorine; namely, spare cylinders, scales, and manifold systems.

A study in the early 1970's of 200 mountain area discharges produced similar information. For the 12 months preceding the study, 51% of the planned discharges had failures resulting in bypassing or discharging of untreated or inadequately-treated sewage due to human error or mechanical malfunction, while 37% of the land disposal systems recorded failures. These failures point to the need for research on equipment design, automation of controls, and into factors relating to human motivation.

Considering the consequences of failure, it is crucial that treatment plant facilities intended to provide water for domestic reuse be designed and operated with a reliability appropriate to the nature of the reuse. In the ultimate this reliability must be fail-safe.

Proposed treatment schemes should include reliability alternatives such as duplicate treatment units, standby units, standby replacement equipment, emergency power supplies, alarm systems, emergency storage facilities, and flexibility in piping systems. These are design elements and cannot assure reliability by themselves. Other "non-design" reliability features are necessary, such as qualified personnel, preventive maintenance, monitoring, and process control programs with appropriate reporting procedures. A scheme to assure reliability must include contingency plans which may provide for diversion to less demanding reuse, diversion to storage with a pump-back system to treatment and to provide for any conceivable problem. We must keep in mind "Murphy's law": Anything that can happen, will happen - and at the worst possible time.

California has developed and is presently in the process of adopting new regulations for reclaimed wastewater to be used for irrigation and recreational impoundments which go beyond present practice and include the above reliability features but do not provide for fail-safe performance. The reliability requirements are based, in part, on the "Federal Guidelines: Design, Operation and Maintenance of Wastewater Treatment Plants" but are not as specific as the requirements specified in the EPA supplement to the federal guidelines entitled "Design Criteria for Mechanical, Electric, and Fluid System and Component Reliability." The proposed California regulations contain, for example, the following sections:

Alarms

(a) Alarm devices required for various unit processes as specified in other sections of these regulations shall be installed to provide warning of:
(1) Loss of power from the normal power supply.
(2) Failure of a biological treatment process.
(3) Failure of a disinfection process.
(4) Failure of a coagulation process.
(5) Failure of a filtration process.
(6) Any other specific process failure for which warning is required by the regulatory agency.

(b) All required alarm devices shall be independent of the normal power supply of the reclamation plant.

(c) The person to be warned shall be the plant operator, superintendent, or any other responsible person designated by the management of the reclamation plant and capable of taking prompt corrective action.

(d) Individual alarm devices may be connected to a master alarm to sound at a location where it can be conveniently observed by the attendant. In case the reclamation plant is not attended full time, the alarm(s) shall be connected to sound at a police station, fire station or other full time service unit with which arrangements have been made to alert the person in charge at times the reclamation plant is unattended.

Power Supply

The power supply shall be provided with one of the following reliability features:

(a) Alarm and standby power source.

(b) Alarm and automatically actuated short-term retention or disposal provisions.

(c) Automatically actuated long-term storage or disposal provisions.

Emergency Storage or Disposal

(a) Where short-term retention or disposal provisions are used as a reliability feature, these shall consist of facilities reserved for the purpose of storing or disposing of untreated or partially treated wastewater for at least a 24-hour period. The facilities shall include all the necessary diversion devices, provisions for odor control, conduits, and pumping and pump back equipment. All of the equipment other than the pump back equipment shall be either independent of the normal power supply or provided with a standby power source.

(b) Where long-term storage or disposal provisions are used as a reliability feature, these shall consist of ponds, reservoirs, percolation areas, downstream sewers leading to other treatment or disposal facilities or any other facilities reserved for the purpose of emergency storage or disposal of untreated or partially treated wastewater. These facilities shall be of sufficient capacity to provide disposal or storage of wastewater for at least 20 days, and shall include all the necessary diversion works, provision for odor and nuisance control, conduits, and pumping and pump back equipment. All of the equipment other than the pump back equipment shall be either independent of the normal power supply or provided with a standby power source.

(c) Diversion to a less demanding reuse is an acceptable alternative to emergency disposal of partially treated wastewater provided that the quality of the partially treated wastewater is suitable for the less demanding reuse.

(d) Subject to prior approval by the regulatory agency, diversion to a discharge point which requires lesser quality of wastewater is an acceptable alternative to emergency disposal of partially treated wastewater.

(e) Automatically actuated short-term retention or disposal provisions and automatically actuated long-term storage or disposal provisions shall include, in addition to provisions of (a), (b), (c), or (d) of this section, all the necessary sensors, instruments, valves and other devices to enable fully automatic diversion of untreated or partially treated wastewater to approved emergency storage or disposal in the event of failure of a treatment process, and a manual reset to prevent automatic restart until the failure is corrected.

Disinfection

All disinfection unit processes where chlorine is used as the disinfectant shall be provided with the following features for uninterrupted chlorine feed: standby chlorine supply, manifold systems to connect chlorine cylinders, chlorine scales, and automatic devices for switching over to full chlorine cylinders. Automatic residual control of chlorine dosage, automatic measuring and recording of chlorine residual, and hydraulic performance studies also may be required. All disinfection unit processes where chlorine is used as the disinfectant also shall be provided with one of the following reliability features:

(a) Alarm and standby chlorinator.

(b) Alarm, short-term retention or disposal provisions and standby replacement equipment.

(c) Alarm and long-term storage or disposal provisions.

(d) Automatically actuated long-term storage or disposal provisions.

(e) Alarm and multiple point chlorination, each with independent power source, separate chlorinator and separate chlorine supply.

As stated earlier these criteria are designed to provide a much higher degree of reliability than now practiced, but do not provide for fail-safe performance. Moreover, reliability of process is a matter separate and distinct from effluent control.

EFFLUENT CONTROL

As with all waste treatment facilities, effluent quality control is necessary - in this case, critically so. For the present, however, this subject cannot be explicitly discussed because essential knowledge is lacking for a definitive discussion. The ingredients to establish quality control are: (1) constituents identified, (2) limits established, (3) knowledge of capability of treatment process to produce desired removals.

As stated earlier, wastewater constitutes a poor source of domestic water supply. This is so because it is apt to contain many potentially harmful substances of varying concentrations. In general terms, the constituents of concern are heavy metals and other toxicants, residual organics, and pathogens - including enteroviruses. To make such a raw material suitable for domestic use, treatment processes must be capable of producing predetermined results. Research is needed to identify constituents, on toxicology of these constituents, and on process development and design. Finally, demonstration projects must be carried on to prove out the entire process in full-scale operations.

In essence, quality control measures are those efforts made to ensure that a final product meets or exceeds previously set standards. In the laboratory these efforts include selection of methods, training of analysts, calibration of instruments, and standardization of reagents, to name but a few. Wastewater reclamation has as its goal production of an effluent with certain measurable characteristics. To achieve this goal the same basic steps are necessary: the treatment method chosen must be capable of producing the desired effect; operators must be properly trained to handle the process; equipment must be calibrated and maintained in optimum condition; and the entire process must be monitored in such a manner that possible problems are identified before they become real problems. Instrumentation must be highly accurate and reliable, provide for continuous monitoring of most parameters and have provision for continual check and calibration. Analytical methods and instrumentation capable of real-time production of information must be developed to provide precise and timely control over treatment processes.

As automation increases and becomes more complex, does reliability decrease? Other questions with relation to monitoring: Is bioassay as a continuous monitoring process feasible; should all reuse systems incorporate batch type systems for release of effluent; to what extent must prospective health status studies be applied to populations receiving water supply derived from renovated wastewater?

A part of the process of effluent control must begin at the point at which wastes are introduced into the system. Source control is an obvious necessity though its value is limited. Source control may take care of the obvious, but what about the unk-unks? With relation to source control, how do we educate the public to eliminate indiscriminate dumping of hazardous material into sewerage systems?

Although many compounds of potential concern remain to be identified and limits and treatment capability established, we do have something to start with. The U.S., the U.S.S.R., and W.H.O. have each developed standards for constituents in drinking water. The U.S. and W.H.O. standards are similar. Among other things, they include a limited coverage for organic constituents. The U.S. standards, in particular, were developed on the basis of starting with the best available raw water quality. It is not surprising, therefore, that they are not broad enough in coverage to provide a suitable set of quality requirements for treatment of wastewater for domestic purposes. Further, it is of interest to note that the U.S.S.R. standards cover [illegible] constituents, the major number of which are for the specific organic compounds. However, most of the U.S.S.R. standards are based on aesthetic and not health considerations.

The EPA findings of [illegible] compounds in only [illegible] of the organics in the water supply at New Orleans gives rise to great uncertainty about the possibilities for future reuse.

Concerns about the role of enteroviruses in disease transmission through the water route poses a special problem. Current water treatment processes are generally believed to be providing safe water starting with raw water sources now in general use. The infectious hepatitis waterborne outbreak at New Delhi gives reason for some special concern, however. In that situation some vagaries of stream flow resulted in changes which brought highly polluted water directly to the water supply intake, said to be a quite unusual situation. The water treatment plant is said to have produced water meeting the coliform standards but a major infectious hepatitis outbreak resulted. If wastewaters are to be used as a source of domestic water, there must be some kind of better understanding of the virus removal capability of various processes under a variety of operating conditions, or there must be a capability for routinely monitoring virus, or both. Without this, the effectiveness and reliability of reuse process to control virus will be in doubt. It is significant to note that, with relation to almost all water quality parameters other than virus in both domestic water and wastewater treatment, performance is monitored on the basis of direct water quality measurements.

One aspect of effluent control is activity by a regulatory agency. Unquestionably, regulatory activity is a necessity to accomplish reliable and effective performance. On the basis of experiences with one major groundwater recharge project, about $[illegible],000 worth of regulatory effort was spent on a [illegible] MGD plant. Beyond this, it is estimated that for this size plant it would cost about $1,000 a year for regulatory activities on an ongoing basis. In round figures, that amounts to $[illegible] per year per MGD capacity. Somehow or other regulatory agencies must receive additional funding for this activity.

CONCLUSION

Present wastewater plants are neither designed nor operated to be fail-safe, though this capability is a necessity for direct reuse. Further, effluent quality control is essential to assure satisfactory plant performance. Much information is needed. We need to know what constituents are apt to be in waste streams and at what concentrations. We need data on acute and chronic toxicity for these constituents in order to establish constituent limits. With this information, it will be possible to determine removal capability for the constituent of concern with specific treatment chains under conditions to be encountered in practice. With this, problems and limitations of effluent quality control can be discussed - but not today.

The two highest research priorities are:

1. Develop information concerning organics in existing domestic water supply sources and provide necessary controls. This is considered to be an urgent need.

2. Study water management techniques for maximum reuse of wastewater taking into consideration health factors and costs in terms of dollars and energy.

DISCUSSION

QUESTION: Mr. Joseph Roesler, EPA-NERC, Cincinnati, Ohio. I would like to make a few comments and then ask my questions.

First, I would like to distinguish automatic process control from manual process control because I am involved in automatic process control. Automatic process control really does not replace the operator. It sort of takes him and nudges him along the straight and narrow line to improve the plant reliability and possibly the plant performance, improve costs, and also provide some quality insurance.

The second thing is if plant effluents are monitored it may also provide plant insurance and reliability, if the monitoring is automatic.

There are two questions I have to ask you: What are your priorities for automation of reuse plants such as the one in Orange County? Which control strategies do you feel would be the highest priorities? My second question is: For the effluents, which parameters would you feel would be most suitable and of the highest priority for automation if you had your choice of anything?

RESPONSE: Mr. Ongerth. Well, I can cope better with the first question than the second one, because I can readily say to the first one, I don't know. I don't know whether we get a greater reliability with automated controls or not. I think this is one of the things we need to do some work on to have better information, to learn what the possibilities are. I know that automatic controls aren't the whole answer.

Maybe Frank Dryden would give us the benefit of an explanation for the breakdown at Whittier Narrows about a month ago.

COMMENT: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. After almost thirteen years of a very successful operation, we did have the failure which was related to the automation of the system in that we do not have operator attendance twenty-four hours a day. We have an ATD alarm system by which certain plant signals are transmitted to an answering service, and one of those kinds of signals is power failure. The answering service has a list of people to call, and they call the operator or someone else who comes and starts the plant up again after everything is checked out, because you can't have a power failure and start everything up automatically because of the load on the system. You have to do it in sequence.

The failure was in the ATD transmission system. They, in fact, knew that their line was not functioning properly and failed to advise us. It happened to coincide during the period they were working on repairing this system that a power outage did occur at night, and because no alarm reached the answering service, we were not advised. The blowers did go off. The plant ultimately began discharging what would have to be considered a rather poor quality effluent which was isolated by the next morning and treated. But it was the kind of breakdown which occurs.

The point I would like to make is that neither Whittier Narrows nor any other plant I know of has been, in fact, designed for fail/safe operation. They have been designed for highly reliable operation; they are designed with certain safeguards built into them for a reasonable amount of protection. But years of previous research, for that matter, on the applications of primary effluents to spreading basins, long before Whittier Narrows was designed, indicate that there isn't any great hazard from even that particular kind of thing, especially for very short periods.

So there has not been an emphasis as there would have to be on an actual fail/safe system. I agree wholeheartedly with Henry and the others who have said that fail/safe systems have not been put together and demonstrated. They haven't even been adequately conceived. That is one of the things that I hope this conference will take a hard look at--what it does take to have a fail/safe system. When we take a hard look at it, we may come to the conclusion we can't afford it. But the fact is that it hasn't been conceived or worked on yet, and when we talk about the potential for potable systems we certainly have to look at the fail/safe controls.

RESPONSE: Mr. Ongerth. I didn't answer the second question. If you want me to try, it won't be a very good answer either. I can't propose automatic monitoring of some constituents that I think would give us the kind of information we ought to have. I think this is another area where we need to develop more information and more knowledge. So, really I can't answer either question.

COMMENT: Mr. Hillel I. Shuval, Director, Environmental Health Laboratory, Hebrew University, Jerusalem, Israel. I would like to comment on this debate with the straw man that Henry has set up.

I think actually what you have proved, and what John Convery has proved, is that actual plants are not very reliable. However, John has proved that you can design a reliable plant if you have to and you can operate it in that way if you decide that you must. I think that the conclusion is actually Frank Dryden's conclusion, that if we are going to achieve the reliability that we all know we need for reuse plants, we have to achieve the type of reliability that John Convery says is technically obtainable and we have to design those plants at a higher level than we are used to. There are consulting engineers who say, "Yes, we'll have to design better." They certainly had better design better, because they cannot get away with a reuse plant that will work only on the average. The same thing goes for fail/safeness. Nobody has tried to design a fail/safe plant, and if we are going to have reuse, we cannot afford to have even minor breakdowns.

One of the things, of course, that we will discuss in this Workshop is monitoring. One of my proposals from a long time back has been that the monitoring should be conceptually different from the water industry's concept of monitoring. The water industry today monitors ex post facto: after they deliver the water, they get the results of the test. This is an untenable position for a delicate product. Even in the milk industry, you've got to get the results of each of the major tests before you deliver the milk. You at least have to show that the milk is pasteurized. So you get a phosphatase test, and possibly, a bacteriological test before you deliver the milk.

So I think it's a whole concept of fail/safe design, a higher level of operational sophistication, monitoring which gives you the results before you deliver the product, with at least a minimum of a twenty-four-hour hold-up in the wet well so you can complete a good part of your chemical and microbiological monitoring tests. I think a good comparison is the industrial example of the atomic energy industry which changed the concept of the electric power industry. The average electric power plant has a history of work accidents and failures and different breakdowns because it is run on the loose basis of many other industries. The atomic energy industry, which has been considered a very risky industry from the very beginning, has had a better accident rate and fewer breakdowns than any other industry because they have been so aware of their stiff requirements.

QUESTION: Mr. Paul D. Haney, Black & Veatch, Kansas City, Missouri. You mentioned Dan Okun. Is he thinking of multiple pipe distribution systems like, for example, dual systems?

RESPONSE: Mr. Ongerth. I am sure that is what Dan is thinking about. Yes. I think that is what he proposed for Singapore. I think this is in some of his writings.

QUESTION: Mr. Haney, Black & Veatch, Kansas City, Missouri. Well, what do you think of that?

RESPONSE: Mr. Ongerth. I think it has its place in the picture. This disposes of the concerns about the organics, for example, in water. If you can produce a biologically safe secondary supply, and if you can cope with the problem of having a dual piping system, than you have an opportunity for reuse in what Schmidt this morning called nonpotable domestic use. I think that has its place.

On Catalina Island, there has been a dual water system for years, with the secondary supply being a salt-water supply for toilet flushing and showers. I think it's the Southern California Edison that now owns the water supply on the island, and they are in the process of abandoning the salt-water supply because of the corrosion problems from salt water. They are going to reclaim effluent, recharge the groundwater basin and pick it up a considerable distance downstream, and that will be their secondary supply. I think this is a very satisfactory arrangement.

COMMENT: Mr. Richard D. Heaton, Denver Water Department, Denver, Colorado. You mentioned your preference for groundwater recharge, and I think of many exceptions. Two stand out in my mind, especially in this area. First, the geology is not amenable to groundwater recharge and we do not have the large aquifer underlying

Denver. Secondly, western water law, specifically the appropriation doctrine, confuses the issue. We are not sure that if we can put x gallons in the ground we are allowed to take x gallons out. If it goes in the ground, we are not sure to whom it belongs.

RESPONSE: Mr. Ongerth. California has a replenishment district law with which I am not at all familiar. Maybe there is something in the California law that would be politically possible for the future. That is certainly a problem. If you pay for recharging it and then you don't control the withdrawals, that is not a very profitable exercise.

HEALTH ASPECTS OF REUSING WASTEWATER FOR POTABLE PURPOSES - U.S. EXPERIENCE

L. J. McCabe
Chief, Criteria Development Branch
Water Supply Research Laboratory
Environmental Protection Agency
Cincinnati, Ohio 45268

ABSTRACT

It is considered that this is a new water resource development and the burden of proof on the safety of such water will be on the utility proposing such use. Types of safety testing of new products are reviewed and cost estimated.

Current water supply health effects research is reviewed and applicability to reuse suggested. Resolved and unresolved problems are outlined.

The most plausable reuse situations are those in which only acute effects need to be considered. The economics of water supply indicate that potable reuse would be cost-effective only in unique situations. Some utility will have to take the pledge to produce water of drinking water quality from sewage for an extended period to demonstrate that it can be done. To date, no one has taken the pledge.

INTRODUCTION

The Environmental Protection Agency has developed a policy that is opposed to direct recycling for drinking water. All drinking water standards developed to date have cautioned that the limits were set in consideration of using the best source of raw water and cannot be used for guidance for wastewater reuse. Thus, any utility that proposes wastewater reuse for drinking water in the immediate future will be required to demonstrate the safety of the processes envisioned without a concensus of regulatory authorities on what will constitute a potable water.

A utility gives an implied warranty of the safety of the drinking water they produce and when there are departures from the current state of the art, there will not be much of a defense to fall back on if consumers claim damage from using the water. To provide an adequate defense would require a tremendous amount of analytical work on the water produced. Data would have to be available on any biological or chemical contaminant that someone could think of. The minimal list provided in the drinking water standards will not be enough. It is likely that the analytical cost will exceed the treatment cost. If damages were sought by a consumer, expert witnesses would be required on any conceivable illness of man that could be enforced to be caused or aggravated by anything that could be measured in water.

Drinking water produced directly from wastewater could be considered to be a new product with many new food additives. Some estimates have been made on the cost of testing new products. Chemical Week reported estimates of $250,000 to $500,000.

It seem obvious that gradual changes will have to be made in the use of wastewater as a resource. Some uses may have a long enough history that they can be considered as part of the state of the art. Industrial reuse has been practiced for enough purposes and in enough locations to be accepted. Much of this has been within plant recycling but the distribution of wastewater for industrial reuse is becoming accepted. The use of treated wastewater for recharge to prevent salt water intrusion has been accepted, but the recharge into aquafers that can be used for water supply will be regulated under the new Safe Drinking Water Act.

It has been stated that direct reuse of wastewater is only a difference of degree from what is practiced now by many cities that use the major rivers of the country for a raw water source. As indicated, the difference of degree makes a difficult problem for a utility but research that is conducted for drinking water purposes should have some application to the reuse situation. EPA has a rather structured research planning system. This begins with statements of research needs from the regional offices, which are combined into Environmental Research Objective Statements in Washington. We receive these EROS's and develop a Research Objective Achievement Plan. Three of these ROAP's have application to the reuse problem.

Reuse Related Research

One of the ROAP's in our Water Supply Research Program is called "Microbiological Contamiants of Water Supplies" and there are several research tasks within this ROAP that do impact on the health effects of reusing sewage for drinking water.

The first of these tasks is one which has concerned itself with providing a technique for concentrating and recovering viruses from drinking water. Concern over the potential problem, and I stress potential, of viruses in drinking water continues to be expressed by a few vocal individuals. Whether or not this is a real problem remains to be determined and one way to attempt to determine if it really is a problem is to look for viruses in drinking water. In order to do this, one must have a technique for concentrating and recovering low numbers of viruses from large volumes of water. We have now researched this to a point where we have a method for the detection of viruses in drinking water, which will appear as a Tentative Standard Method in the forthcoming 14th edition of Standard Methods. This technique could, we believe, be effectively used to monitor for viruses in drinking water made from sewage, if we ever have to go to that extreme.

The system we use to monitor viruses in drinking water basically consists of passing water under pressure through microporous filter media to which the viruses adsorb. The viruses are not sieved out of the water by virtue of the pore size of the filters, in fact the filters are 36 to 286 times as large as most enteric viruses. The viruses are adsorbed to the microporous filters by simply adjusting the pH of the input water. Once viruses have been adsorbed to the filters they can be eluted from the filter with a small volume of an alkaline pH buffer. By appropriate manipulation we can concentrate the viruses in 500 gallons of water into a 20 ml volume. This entire 20 ml volume can readily be assayed in tissue cultures or animals for viruses. With this system we have been able to detect one virus unit in 100 gallons of Cincinnati tap water which was seeded with one virus per 100 gallons, if we sampled 500 gallons.

We have been evaluating a microporous filter system in our laboratory and in field surveys for viruses in drinking water. These are Balston filters, made of fiberglass-epoxy resin and are about 2 1/2 inches long and 1 inch in diameter and have an 8 micron porosity. They are normally used as a three filter unit system and we have not experienced filter clogging problems with this system with samples as large as 500 gallons of drinking water.

I mentioned that we have used this type of filter system and others, in field studies for viruses in drinking water. This field study or survey is another task which relates indirectly to the health aspects of reuse problems. For the past 1 1/2 years we have been conducting a virus in water study of finished water from several communities in the United States and are continuing these studies. These studies are a continuation of work conducted in our three field laboratories at an earlier date, before these lab's functions were transferred to Cincinnati. The studies have a two-fold purpose - (1) to determine if human enteric viruses can be detected in treated finished drinking water; (2) to field test the virus concentrating equipment and procedures as they are improved by ongoing research in our laboratory. In these current studies a primary criterion for selection of sites was the plant's utilization of a surface source water having high fecal coliform counts - as near to the sewage reuse as we could find. So far we have collected seventy-five samples and in no case have we detected viruses in the finished water. Our sample sizes have ranged up to 500 gallons. The fact that these water treatment systems were challenged by a very poor source water on numerous occasions and yet produced a finished water in which no viruses could be found would seem to give a vote of confidence to the adequacy of virus removal of good conventional treatment. One would certainly hope that "advanced" treatment processes, as used in reclaimed water processes, would do a better job, and thereby assure us that they too eliminated a virus problem, if there is indeed such a problem.

One final task in this ROAP that relates to reuse should be mentioned. There is a need to develop and evaluate techniques that can be used to monitor the "infectious disease" history of populations who may use or be exposed to reused sewage. We are funding a research group that is investigating the use of the serological-epidemiological approach to determine the health risk of employment as a sewer maintenance worker as compared to road maintenance workers. One would expect that sewer workers would have a higher risk of exposure to infectious agents in sewage than would road workers and that this risk could be measured by comparing the "infection history" of the two groups. "Infection history" does not necessarily mean sickness, it means exposure to, and infection with, a biological agent. The individual may or may not become sick, but in all likelihood he will develop an immunity to the agent. This immunity can be determined by serological tests on his blood serum and if enough of the proper tests are done, can indicate the biological agents which have infected the individual over the years. If we can demonstrate the usefulness of this technique it certainly can be considered as a technique for monitoring the infectious disease exposure to persons contacting reused sewage.

The knowledge and data obtained in setting health-related standards for drinking water can certainly be used, at least initially, in the evaluation of wastewater that is to be recycled for domestic uses. We should remember, however, the limitations of these data. The Drinking Water Standards cover only a small number of constituents and the speciation or matrix effects may be different in reclaimed wastewater than presently used drinking waters.

The research being conducted and planned by EPA on the health effects of various inorganic contaminants in drinking water will be discussed briefly to acquaint you with our approach to obtaining the needed data. This will provide, at least, a point to begin discussions on whether this approach should be applied to reclaimed wastewater and what areas are of a mutual interest so that duplication can be avoided.

Our health effects research on inorganic contaminants can basically be divided into five broad categories:

(1) occurrence;
(2) body burden studies;
(3) toxicological studies;
(4) epidemiological studies; and
(5) rapid screening for mutagens and carcinogens.

Our research up to the present has primarily been to obtain health effects data to strengthen the present inorganic standards. Before we can conduct studies on other contaminants we must first identify and quantitate the contaminants to establish a priority for study. We are currently sampling water supplies in 35 areas of the country to obtain these data. We felt that multi-elemental analytical technology which has been used successfully in analyzing other media such as rock, soil, air, had reached the point that it could be successfully applied to water. The advantage of a multi-elemental technique is the measurement, simultaneously, of a large number of elements in the ppb or less concentration. The problem in water analysis is that of limited experience by analysts in this field. When determining concentrations in the ppb range, contamination in sampling and preparation are of course a major source for error. Other problems relate to quality control and appropriate internal standards. We are currently contracting with Dr. Paul C. Simms of Purdue University for this analytical work. He is using proton-induced X-ray emission, which is capable of determining 82 elements (Silicon through plutonium). Approximately 30 elements can be determined at a sensitivity of ± 1 ppb at the present time. With additional instrument modification and appropriate standards, it is hoped that the additional elements can be determined at the same detection level in the future.

Another way to approach the problem of setting priorities on constituents to study is to determine human body burdens and look at all routes of exposure to arrive at the contribution from water. This has been done to a small extent but more will be done in the future. The problem in studying living populations is to select a tissue such as scalp hair or nails which will represent body burden for the particular element desired and which will easily be given up by the population sampled. Autopsy studies will also yield important information in this regard.

Our toxicological studies are designed to measure specific end points according to the type of effect anticipated. These studies have been with single contaminants ingested at varying dosages. Our in-house capabilities include an animal model to study effects on brain function. This has been used to substantiate the mercury standard and is currently used to study the effects of manganese and lead. Other animal studies, completed or planned, include nitrate, cadmium, selenium, molybdenum, silica, and barium. Future studies will consider the possible interactions of various contaminants.

A question we consider of importance, especially in the area of water quality and chronic disease is the question of bioavailability of various inorganics in water as opposed to food. For most inorganics, exposure via food is greater than that obtained by drinking water; however, metals in water may be more readily available. Bioavailability can be studied in animal models.

While animals are useful for studying mechanisms and providing good data that can be extrapolated to man, epidemiologic studies have the advantage (and disadvantage) of looking at man directly over a long exposure period and taking into account all the conflicting variables present in real life. This approach was used by us to study the effects of nitrate and lead in drinking water and will be used to study populations exposed to barium in ground water. Our major effort in this area has been to relate water quality to chronic disease problems such as cadriovascular. We are currently cooperating with the National Heart and Lung Institute on a prospective study of trace elements in water and cardiovascular function of 4200 individuals in 35 areas of the country.

Our work in rapid screening techniques for the detection of mutagens and carcinogens has been limited to the use of bacterial indicators and cultured mammalian cells. A grantee at Louisiana State University Medical Center in New Orleans is using Bruce Ames salmonella testing strains to screen raw and treated water from the lower Mississippi River for the present of carcinogens. The water is assayed both directly and after liver-activation to determine if the tester strains revert to histidine independence. The grantee is also investigating a number of mammalian cell lines which could be used to assay water samples. In-house, we are currently screening a number of inorganics to assess mutagenic potential. These include arsenic, berryllium, cadmium, cobalt, nickel, selenium, barium, chromium, copper, lead, manganese, mercury, and zinc.

Rapid screening techniques such as these can be applied to wastewater reuse. Ames testing system provides results in approximately two days and is quite easy to use. The problem of course is determining which screening method will provide consistently low-false negatives. These systems could be used for monitoring particularly with ground water recharge which allows for a less dynamic cycle.

The third ROAP of interest concerns the Occurrence and Effects of Organic Contaminants in Drinking Water. The major thrust of this project is to obtain concentrates of organic chemicals from drinking water and then subject these total concentrates to toxicity testing. We have considered several techniques of concentration and have put most effort into reverse osmosis. A report from a contractor, Gulf South Research Institute, has recently been received - Evaluation of Semipermeable Membranes from Concentration of Organic Contaminants in Drinking Water. We have been collecting organic concentrates from Cincinnati drinking water on a regular bases for over a year. A cellulose acetate membrane is used for the first recovery and then the permeate is processed by a Permasep membrane. The concentrate from both processes is lyophilized for further reduction in volume. Both RO concentrates are then extracted with pentane and methylene chloride to remove the organics from the salts. We have been able to only partially complete what we want to do with these concentrates, but are satisfied that useful data can be obtained with the material recovered in this way. Some of the chemical characterization has been completed but a problem that must be resolved is an appropriate blank for this processing. The water comes in contact with several materials in the processing and contamination does occur and must be quantified. The toxicity testing has started including acute toxicity, mutagenicity screening, and carcinogenicity pre-screening. The amount of material recovered limits what can be done on each sample. A sample for toxicity testing cannot have complete chemical characterization and only partial chemical workup is done on some samples. As the screen techniques are better understood, it may be possible to reduce the material required.

The organic recovery and toxicity testing studies are being extended to five other cities and the RFP's for these are out. We also have a Request for Proposal to better separate the salt from the organic material. We have felt that the study of of combination of the total organics in the water would provide the most useful data. Synergenic effects would be automatically considered and the research might lead to a general organic parameter that could be used to control water quality. There have been improvements in organic chemistry that make it difficult to keep to this research plan. Specific identification can now be made with the Gas Chromatograph/Mass Spectrophotometer. When specific identification is done and quantities determined, interest is developed in obtaining specific toxicity data on the compounds. We are therefore carrying out research on the toxicity of haloethers and the halogenated aromatic hydrocarbons.

The most interesting development was the finding of chloroform and the other methanes using a volatile organic analyzer developed by the Methods Development and Quality Assurance Research Laboratory. We used this tehnique on the New Orleans drinking water and are continuing in the National Organic Reconnaissance Survey that followed. This workload has postponed some of the things we had planned to do but it also questions the possibility of collecting the total of organic chemicals by one technique. It seems unlikely that one method will recover all organics and there will have to be a blending of fractions for toxicity testing. Nothing is known about the toxicity of the bromodichloromethane and dibromochloromethane and this will require some specific toxicity workups.

There are three main objectives to our research on organics - (1) determine the compounds present in tap water; (2) elucidation of the toxic properties of these compounds singly and in combination in appropriate animal models, and (3) monitoring of human populations to verify predicted presence or absence of disease. All of this will be applicable to wastewater reuse.

Reuse Research

We also have a ROAP on the Health Effects Associated with Consumption of Renovated Water that is in its second year of funding. It is designed to follow up on developments from the water supply research and apply the techniques to treated wastewater. The organic chemical concentration techniques are being applied to advanced waste treatment effluents. The total non-volatile organic carbon (TNVOC) is about 2 ppm in Cincinnati and New Orleans drinking water. When sampled the Dallas water was down to one ppm but the others all had more TNVOC; Tahoe - 5 to 9; Blue Plains - 5, and Pomona - 3 ppm. The Bellar VOA technique was also applied to the product waters of these plants and 14 to 18 compounds identified; this could be compared to the 17 reported for New Orleans. Preliminary judgment would be that the AWT effluents have more organic contaminants than some drinking waters.

We have also had the multi-elemental analytical technology applied to the Blue Plains effluent. Three diurnal cycles were obtained using proton-induced X-ray emissions. In this situation we were not satisfied that useful data had been obtained, but it would seem that for the metals with limits in the drinking water standards the effluent would meet the limits on average but not consistently. The limits are based on chronic intake but it may also be necessary to develop a one sample limit to control peak concentrations.

We are evaluating the component cost of water supply to see how reuse might work into the water resource development. A concern has developed on the premise of "economics of scale." It is recognized that this applies to the treatment plant but not to the total distribution system. To control transportation and distribution cost it might be best to develop new sources at the extremeties of the distribution system and reuse might have a role in this.

Another research task is in cooperation with EPA industrial waste research. Recycling systems are being developed for all industries and there are particular health effects problems in food processing. We will evaluate the effects of recycling in a poultry plant. The judgment on health effects will be based on the evaluation of the finished product to show that is is no worse than the regular product. Once the first bird is processed, there is an averaging out of contamination with all the subsequent birds processed, but recycling can also retain some of the chemicals that are used in the plant that normally do not have contact with the product.

SUMMARY

It should be obvious that it will take some time before there will be enough research completed to allow reuse for potable purposes. When chronic toxicities must be considered there must be research on many aspects of the problem at very low concentrations. If there are reuse situations where only acute effects need to be considered, it should be possible to reuse wastewater sooner. Continued consumption of the water would not occur in recreational use; it might be possible in this situation to consider only the infectious disease problems. This same idea could also be applied to dual water systems with the lower grade water only safe for acute exposure and of such quality that the difference could be detected by taste.

When the complexity of the problem is appreciated, it can be seen that the reuse idea will only apply in a unique situation for some time. It will clearly have to be a least-cost situation by a wide margin to justify the long-term risk that may be involved.

To evaluate the possibility of reuse, it will be necessary to produce a potable water for an extended period without using it for potable purposes. No utilities seem to be ready to do this.

DISCUSSION

COMMENT: Mr. Dolloff Fred Bishop, U.S. EPA, Cincinnati, Ohio. Lee, I would like to make one comment on the TOC residuals that you were talking about in the AWT effluents. First, you cited Dallas which was a specific, high quality treatment sequence aimed at getting close to the potable reuse approach. The other AWT systems that you cited were systems which were designed to meet some other standard. For instance, Lake Tahoe was not designed for producing as low a residual organic carbon as possible. The Blue Plains facilities, which you alluded to, were also either the advanced biological systems which had no carbon adsorption in them, or the physical-chemical systems on the raw wastewater which, again, did not have any final organic polishing steps such as ozonation. Under these sequences then, the 5 mg/ℓ TOC level which you suggested you found there could be expected. With one more existing technology step, it should be possible to reduce these levels to the order of 2 to 3 mg/ℓ that you are finding in many of the surface-water supplies in the United States.

RESPONSE: Mr. McCabe. May I respond to that? Are you going to ask a question about that?

RESPONSE: Mr. Bishop, U.S. EPA, Cincinnati, Ohio. No. I was stating that as a source of information.

RESPONSE: Mr. McCabe. That's my problem. That's why I said at the very end of my talk that somebody is going to have to take the pledge, "I'm going to make drinking water for you long enough to test." This has not been done to date. Where are you going to do it? Everybody says, "Oh, go to Tahoe. They've got a great effluent there."

COMMENT: Mr. Bishop, U.S. EPA, Cincinnati, Ohio. We haven't put in a system until just recently. For instance, you have the Blue Plains plant now and there is a pilot chain which is designed to produce high quality effluent which we hope will be approximating that for drinking water, and that is what its specific assignment is. So perhaps we will be able to give you some of those answers.

RESPONSE: Mr. McCabe. Yes, but my four years of needed health effects research don't start until you're ready with the effluent.

COMMENT: Mr. Bishop, U.S. EPA, Cincinnati, Ohio. The major point that I would like to make is that I think we may be missing the whole issue in today's discussion. We have been arguing two sides of perhaps the same coin. The residual trace organics and components which we don't wish in our reuse effluents, and that we are concerned about, are also found in our surface-water supplies. They may be diluted, but they are still there. And if we find that they are undesirable from an ecological point of view or from a human health effects point of view, we are probably going to have to go after them in the water supplies as well as in the treatment plant. We may not be able to get off this hook no matter how we look at it.

RESPONSE: Mr. McCabe. But the utility won't get sued in the meantime because he is practicing the current state of the art.

COMMENT: Mr. Bishop, U.S. EPA, Cincinnati, Ohio. You're sort of arguing the legal aspect rather than a true health effects aspect.

RESPONSE: Mr. McCabe. Well, Mr. Quarles went up to Boston to talk about my research, so I figured I would come down and talk about the law.

QUESTION: Professor Shuval, Director, Environmental Health Laboratory, Jerusalem, Israel. I realize that we are treading on administrative ground, but I tend to agree with Fred Bishop that the issue we should be discussing here is the scientific issue and not the administrative issue. And I think that you pointed out that the research program that you are carrying out now will provide some of the answers for reuse of water, whether it is direct or indirect. If we accept the reality that we are living in a world where we have indirect reuse of water (I think the figure was given that something like 50- to 100 million people are using more or less reuse water), then we must have the answer to: What are the health effects of using water directly or indirectly? What is the treatment technology that is required to remove these things? I think it is almost administrative quibbling to say, "Well, it's premature to think about direct reuse." You still have to have the answers whether you never go into direct reuse. You still must know how to concentrate the organics; you still must know how to fractionate them; you still have to know which are the toxic ones; you still have to know the effects of the mixed bag and each one separately; and you have to know how to remove them if they are metals.

RESPONSE: Mr. McCabe. But you don't have to assay AWT effluents unless you're planning to use the water for human consumption.

COMMENT: Professor Shuval, Director, Environmental Health Laboratory, Jerusalem, Israel. Yes, you do, because you have to develop a treatment technology. I don't care whether you call it advance waste treatment or advance water treatment; it's the same thing. But you've got to remove these things, and whether you call it waste treatment technology or water treatment technology, it's exactly the same technology. Whether you put your carbon filters on the waste treatment plant and also on the water treatment plant, or you bring them together, you must have a technology that will remove the total organics or the nonvolatile organics as well as the volatile organics and the metals and all of the other things that you want to get rid of.

We faced this recently at the Amsterdam meeting of the WHO where we came to the conclusion that we would just change the name of the meeting. The original name was "Health Effects of Direct Reuse," and they changed the name to "Health Effects of Direct and Indirect Reuse," because you must address yourself to the same question, and the water supply people and the wastewater people both require answers.

Henry Ongerth is right. You still may decide that you don't want to go into direct reuse because of other complications. But whether you go into it or not, you must answer all of the same questions and you must have a technology to be able to remove these things.

QUESTION: Mr. Gerald Berg, Methods Development & Quality Assurance Research Laboratory, NERC-EPA, Cincinnati, Ohio. Lee, did I understand you correctly that you believe you can now recover one virus particle in a hundred gallons of water?

RESPONSE: Mr. McCabe. Yes.

QUESTION: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. Did you have a reliable method for doing this?

RESPONSE: Mr. McCabe. Yes.

QUESTION: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. You believe you have a reliable method for doing this?

RESPONSE: Mr. McCabe. Unless you are going to ask me about hepatitis.

QUESTION: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. No. I'm not asking you about hepatitis at all. I'm talking about the overall problem. You believe you have a reliable method for doing this. Does this mean that you are now out of the methods development business?

RESPONSE: Mr. McCabe. We calibrated a method. We were able to calibrate it to show that that's what its sensitivity was. One per hundred gallons when you do five hundred.

QUESTION: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. All right. I'll pass over that last question. Let me ask you this. Would you tell us how many different tap waters of how many different qualities you tested in order to come to that conclusion?

RESPONSE: Mr. McCabe. In my recollection, it was about twelve, Gerry.

COMMENT: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. Twelve waters, you've based that conclusion on just twelve waters. All right, I have one other question.

RESPONSE: Mr. McCabe. But the point I was trying to make is that we've got a way in which you could go if you want to make drinking water out of wastewater.

COMMENT: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. But we're talking about methods for testing and determining treatment reliability and safety of water.

RESPONSE: Mr. McCabe. O.K. We've got one, but it's got to be applied.

QUESTION: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. But you're basing the assumption that you have a method on only twelve different tests, twelve waters?

RESPONSE: Mr. McCabe. Yes. But some of them were softening plants and some were not.

QUESTION: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. Well, I think we have a longer way to go than that. Let me ask one more question. You tested seventy-five different waters in different parts of the country for viruses with this system. Correct?

RESPONSE: Mr. McCabe. Well, we had to go to some that were close because there was a mileage problem with gasoline.

QUESTION: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. That's all right. I have no objections. There were seventy-five plants tested, and you said that along with these tests you ran a control test in which you added a known amount of virus. Would you tell us the efficiency of recovery of virus from those controls, not whether or not you got any but what the efficiency was?

RESPONSE: Mr. McCabe. I think the efficiency was about sixty percent. But, you see, that's why we have to check. To tell you we got one in a hundred, we have to run five hundred.

COMMENT: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. I understand that, Lee. But as I recall, the efficiency varied considerably from test to test and it wasn't that high.

RESPONSE: Mr. McCabe. Well, it does vary. Yes.

COMMENT: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. Considerably. What I am saying is that I don't think we have reliable methodology yet.

RESPONSE: Mr. McCabe. We have had a long argument about whether the way to proceed with this thing was percent recovery or "Yes" or "No." You mix up a batch of a known level and let me know when I can get them. That's what I have been pushing them to do.

COMMENT: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. I don't really want to push you up against the wall on this, but it's impossible to test on a "Yes" or "No" basis, because the more you put in, the greater the likelihood of "Yes": the less you put in, the greater the likelihood of "No."

RESPONSE: Mr. McCabe. Yes. But maybe we have a batch that might be like drinking water at its worst, and then tell me where you can find them. That's the premise.

QUESTION: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. That's not really "Yes" or "No." Then you are taking a certain percentage of recovery. You are setting it up to give you a certain percentage of recovery. That's not unreasonable. But what I am asking you is: Do you know what the percentage of recovery of this is?

RESPONSE: Mr. McCabe. That's the problem. We can tell you whether there's one in a hundred if you'll let us look at five hundred gallons.

COMMENT: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. What I'm saying to you is I don't think you really can with any degree of reliability. I don't think you have done anywhere near enough tests on nearly enough different kinds of waters.

RESPONSE: Mr. McCabe. That is why we have written up as a tentative method in Standard Methods so that a lot of people can try. Maybe it only works in our hands.

COMMENT: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, Cincinnati, Ohio. The Standard Methods is another problem. But I don't think I want to take time here for that now. We'll take care of that in the workshops later on.

COMMENT: Mr. Mark D. Sobsey, University of North Carolina, Chapel Hill, North Carolina. I disagree with the premise that the methodology for viruses is that good. The methodology that has been developed and tested has been tested almost exclusively with enteroviruses. It has not been tested with hepatitis Type A or with the agents of viral gastroenteritis because we can't work with those agents, nor has the method been systematically tested with adenoviruses and reoviruses which are viruses of public health concern in water. I think that additional work is needed, and I agree with Gerry on this point that additional work is needed on methods development before we can say, with some degree of assurance, that, in fact, we have a reliable method and that the reliability of the method has been demonstrated with representatives of the several different groups of enteric viruses that are of public health concern.

RESPONSE: Mr. McCabe. We are doing reovirus. The reovirus seem to die pretty easily when they know they are going to get chlorinated.

QUESTION: Mr. Richard Symuleski, National Bureau of Standards, Washington, D.C. In consideration of Mr. Shuval's earlier comments on rapid monitoring of microbiological contaminants in water, are you doing any work on GC or MS for taxinomic identification of pathogens?

RESPONSE: Mr. McCabe. I don't think you need rapid monitoring.

QUESTION: Mr. Symuleski, National Bureau of Standards, Washington, D.C. Before you release a product?

RESPONSE: Mr. McCabe. I don't think you are going to be quick enough to be of much value to people. You are better off basing your acceptance on whether that water is O.K. to go. If it has a chlorine residual, a turbidity of so and so, and a contact time of such and such, you pump it out. You are not going to be able to sit there and wait for the virus results to see if water is fit to pump to distribution.

QUESTION: Mr. Symuleski, National Bureau of Standards, Washington, D.C. In a situation where you have, let's say, twenty-four or forty-eight-hour turnaround time on your microbiological parameters, wouldn't a higher degree of reliability with rapid identification give you the possibility?

RESPONSE: Mr. McCabe. No. I think John ought to know his treatment train well enough that he knows that if he treats it this way, you're not going to have to worry about it. Now in a research sense, we are going to follow them. But then when you actually go to applying it, I don't think you are going to have real-time monitoring except for those things that we have spoken of as part of your control of the treatment itself.

QUESTION: Mr. Symuleski, National Bureau of Standards, Washington, D.C. Then there is little interest in improving microbiological test methods?

RESPONSE: Mr. McCabe. There is little interest on my part. Yes.

COMMENT: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. Although I think there is perhaps more to say to the question of the need for rapid testing because I am in favor of more rapid testing, that wasn't what I wanted to speak to. I wanted to speak to your opening remarks concerning the problem of a utility proceeding with a water reuse program in some direct sense. I would like to point out that your concern is a valid one. I don't think any single agency, whether it be a utility or a health department, should be alone in trying to make a decision as to whether a particular reuse is or isn't acceptable technologically, or publicly, or in any other way. This is why the joint statement of the AWWA and the WPCF advocated a national, well-funded, interdisciplinary study which would take into account all of the various interests in water reuse: the doctors, the AMA, the health people, the universities, the water people, the wastewater people. All of these have to come together somehow and conceive of a program. I figure that what we are doing these three days is part of that: where we conceive of a program that ultimately will be carried out over a period of ten years or fifteen years, whatever it is going to take to put the treatment chains together and to do the biological, organic, and epidemiological studies so that finally we get to the point where people can agree that we either do or you don't have a system which is viable. Such a system must be proven so that people can go ahead and use it without standing alone while other people in the wings who didn't participate take pot shots at them. I think it is essential that it be done in a unified way.

RESPONSE: Mr. McCabe. Thanks. That is a good summary.

EVALUATION OF THE HEALTH ASPECTS OF REUSING WASTEWATER FOR POTABLE PURPOSES IN ISRAEL

H.I. Shuval
Associate Professor of Environmental Health
Hebrew University - Hadassah Medical School
Jerusalem, Israel

ABSTRACT

Water supply in Israel for agricultural, industrial and municipal purposes is currently utilizing over 90% of the country's potential water resources. By the year 1980 there will be an anticipated water deficit which will reach major proportions by the year 2000. In 1973 some 20% of the available municipal wastewater was utilized primarily for agricultural purposes. The Dan Region Water Reclamation Project has been designed for municipal and agricultural reuse of the wastewater of Tel-Aviv as well as six other neighboring municipalities with an estimated future population of 1,700,000 and a wastewater flow of 0.44 MCM/day (116 MGD). The reclaimed water will be directed to areas in the south and will not be subject to multiple recycling. The present plans of the designers call for biological and physical-chemical treatment, and recharge of effluent through sand dunes. The reclaimed water will be pumped by a series of recovery wells which are designed to provide for a 400 day residence time in the aquifer. Since it is the intention of the planners to provide reclaimed water with a quality suitable for all uses including potable purposes, further treatment of the water withdrawn from the aquifer by such processes as activated carbon filtration and ozonization are being considered for the removal of refractory organics. A preliminary program to evaluate the suitability of the reclaimed water for human consumption has been initiated. The study includes chemical analysis for toxic organic and inorganic materials as well as subchronic and chronic feeding experiments of rats with concentrates of the residual organics from the reclaimed water. Testing for the microbial safety of the water is also an essential part of the test program and includes developing rapid techniques for concentrating and detecting enteroviruses in water samples as large as 400 liters (100 gals.). The methodology of the program to evaluate the health effects of the reclaimed water is presented.

INTRODUCTION

Israel's Water Requirements

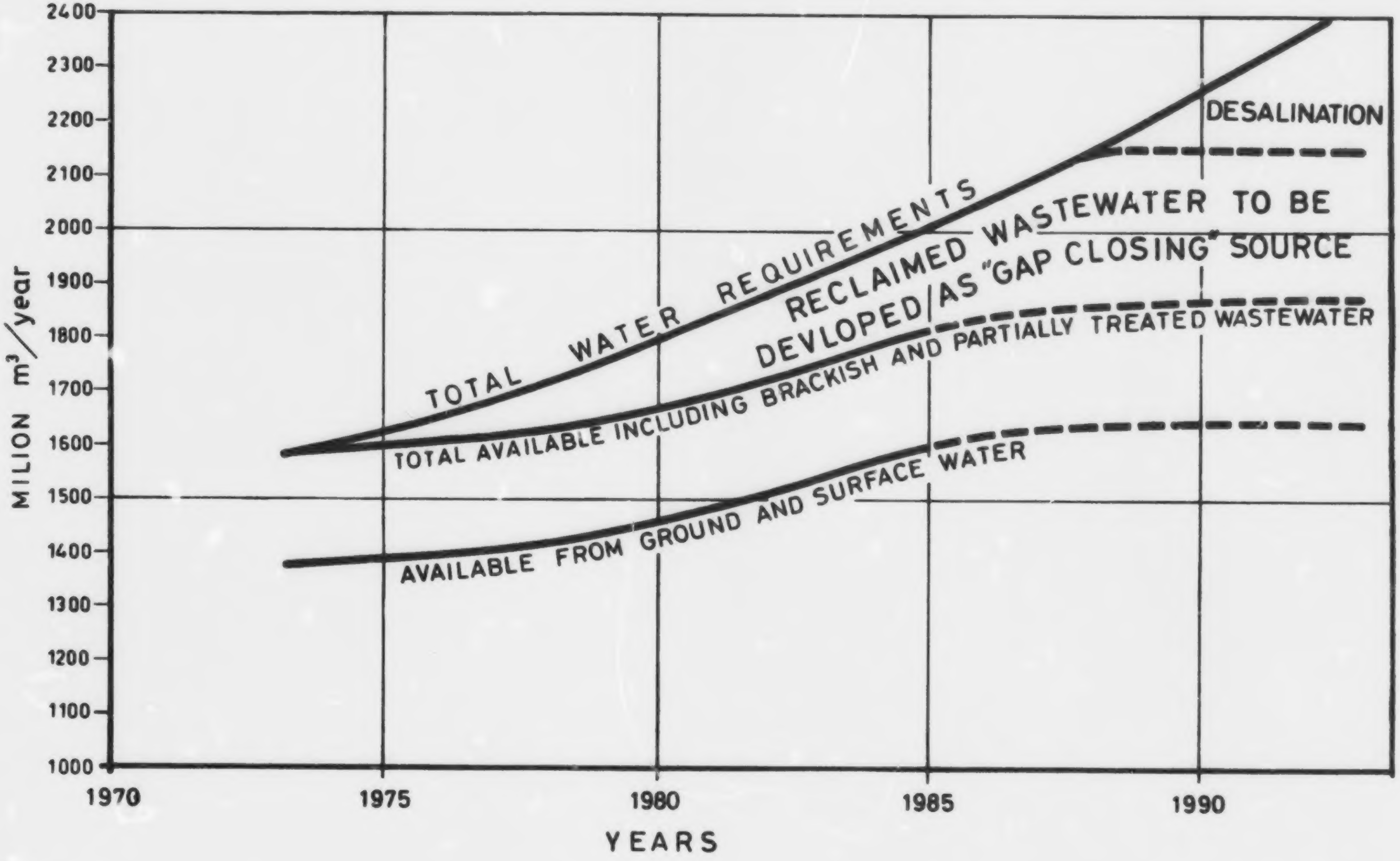
The severe limitations in natural water resources have become a critical facttor in the development of Israel and has led to an intensive search for alternative sources of water including the reuse of wastewater.

Israel is a small country with a rapidly developing economy and a high rate of population growth due primarily to an open immigration policy. The population in 1974 reached three and one half million and has more than quadrupled since the country achieved its independence in 1948. The area under irrigation increased more than five fold during the same period. Rainfall reaches an annual average of 550 mm/yr (22''/yr) in the central coastal plain and drops to 25mm/yr (1''/yr) at the southern tip of the country.

Large scale water supply development projects have tapped most of the countries water resources and it has been estimated that current water supplies for agricultural industrial and municipal purposes are

FIGURE Nº 1

WATER REQUIREMENTS VERSUS RESOURCES AVAILABILITY IN ISRAEL



utilizing over 90% of the country's potential water reserves. The quantity of water supplied in 1974 was 1,600 million cubic meters per year (MCM/yr) ($4x10^5$MG/yr).

It is estimated that the country's population will reach well over four million by the year 1985 at which time the total water requirements will be 2,000 MCM/yr ($5x10^5$MG/yr) some 200 MCM/yr ($5x10^4$MG/yr) above the quantity estimated as being available from known ground and surface sources (1) (Figure 1).

Intensive studies of alternative sources of additional water supplies needed to close the gap have been carried out including desalination of sea and brackish water, rainfall supplementation and wastewater reuse.

Before the recent drastic increase in the cost of energy, desalination of seawater was considered as an expensive although inevitable alternative water source which could at something under $1/1000 gals meet growing municipal and industrial needs. Current cost estimates for desalination of $4-5/1000 gals cast serious doubts as to its economic feasibility except as an absolute last resort.

Studies carried out in Israel on rainfall supplementation by cloud seeding have produced promising results with statistically significant rainfall increases of some 10% over a five year period. This program has now become operational but will not itself solve the severe water shortage that is developing.

As early as 1956, the reuse of wastewater was included in the National Water Plan as an essential future water resource. Early wastewater reuse efforts were directed mainly towards agricultural utilization and by 1973 some 200 reuse projects were utilizing 20-25% of the potentially available municipal wastewater (2). A number of projects for reuse of wastewater by industry have also been successfully developed.

Israel's water planners now visualize the rapid development of wastewater utilization projects as an economically attractive interum measure to close the gap in the growing water supply deficit and thus postponing for as long as possible the large investments and high operating costs associated with sea water desalination.

However, even with the full development of all planned wastewater utilization projects by 1985 it must be recognized that this source is limited and that eventually the only foreseeable solution to provide the additional water required will be through large scale desalination of seawater. It is anticipated however that by postponing such plants for 10-15 years, technological progress made during the interim will hopefully reduce the costs.

The five year national plan for water resources development in Israel envisages the implementation by 1980 of several major wastewater reclamation projects, of these the Dan Region Water Reclamation Project will be the largest and will contribute .247 MCM/day (65 MGD) growing to 0.44 MCM/day (116 MGD) by the year 2000 (1). This project has as its goal the production of a water suitable in quality to meet all requirements including potable purposes.

Reuse of wastewater as compared to seawater desalination can be seen as a relatively low energy demanding alternative water source. Simply from the point of solids removal requirements it can be pointed out that only about 1000 ppm of solids must be removed from wastewater while 30,000 ppm must be removed from seawater to meet equivalent drinking water standards. However, there are many unique problems that must be dealt with in wastewater renovation including the inactivation of pathogenic microorganisms and removal of refractory organics which may be toxic at very low concentrations. The ability of advanced wastewater treatment technology to meet these problems will be the real test as to the competitiveness of wastewater reuse.

The remainder of this paper will be devoted to questions associated with evaluating the health aspects of reusing wastewater from the Dan Region Water Reclamation Project for potable purposes.

DAN REGION WASTEWATER UTILIZATION PROJECT

The city of Tel Aviv, Israel's major metropolitan center and six neighboring municipalities have joined together to form the Dan Region Sewerage Association to solve their common wastewater disposal problems. Two other townships are also planning to join in the near future.

The region's main mode of wastewater disposal is through outfall sewers to the sea leading to serious pollution of nearby Tel Aviv bathing beaches (3).

The Dan Region Wastewater Reclamation Project was initiated in the early 1960's by Tahal-Water Planning for Israel with the aim of solving the problem of beach pollution and of recycling the large volumes of wastewater to the national water system (4) (5). In 1974 the total population included in the region was about 1,000,000 persons. The estimated population for 1985 is 1,300,000 reaching about 1,700,000 in the year 2000. Total mean water consumption of the region in 1974 was .3 MCM/day (75 MGD). Estimated water consumption for 1985 is .41 MCM/day (103 MGD) reaching .55 MCM/day (137 MGD) by the year 2000 (1).

Both due to the recent drastic increases in the costs of energy which has made seawater desalination an impractical alternative water source at this time, and the urgent need to reduce the pollution of the Tel Aviv beaches, the Dan Region Project has been given the highest priority in the national water resources development program. The project is now in an advanced stage of design and construction.

The Dan Region Project includes the construction of major intercepting sewers to convey the wastewater from all the towns in the region to the treatment site in the sand dune area along the coast south of Tel Aviv. There, the wastewater will be processed by biological and chemical treatment processes prior to pumping the effluent to recharge basins located on the sand dunes. The water will be pumped from the aquifer by a series of recovery wells located several hundred meters away from the recharge basins. The recovery wells have been designed to provide for a residence time of some 400 days in the aquifer and for a degree of dilution, with the ground water. The reclaimed water extracted from the acquifer will then receive final polishing treatment and further dilution depending upon its intended use. The reclaimed water will be conveyed mainly to the Negev area south of the Dan Region and will therefore not be subject to multiple recycling. This will avoid the problem of build up of dissolved minerals and refractory organics with its many associated complications.

Since it is one of the goals of the project to produce water of a quality suitable for domestic consumption, consideration must be given to additional treatment to remove potentially toxic residual organics and totally inactivate all pathogenic bacteria and viruses. Filtration in activated carbon columns and ozonization are possible final treatment stages to be provided for the reclaimed water intended for domestic use.

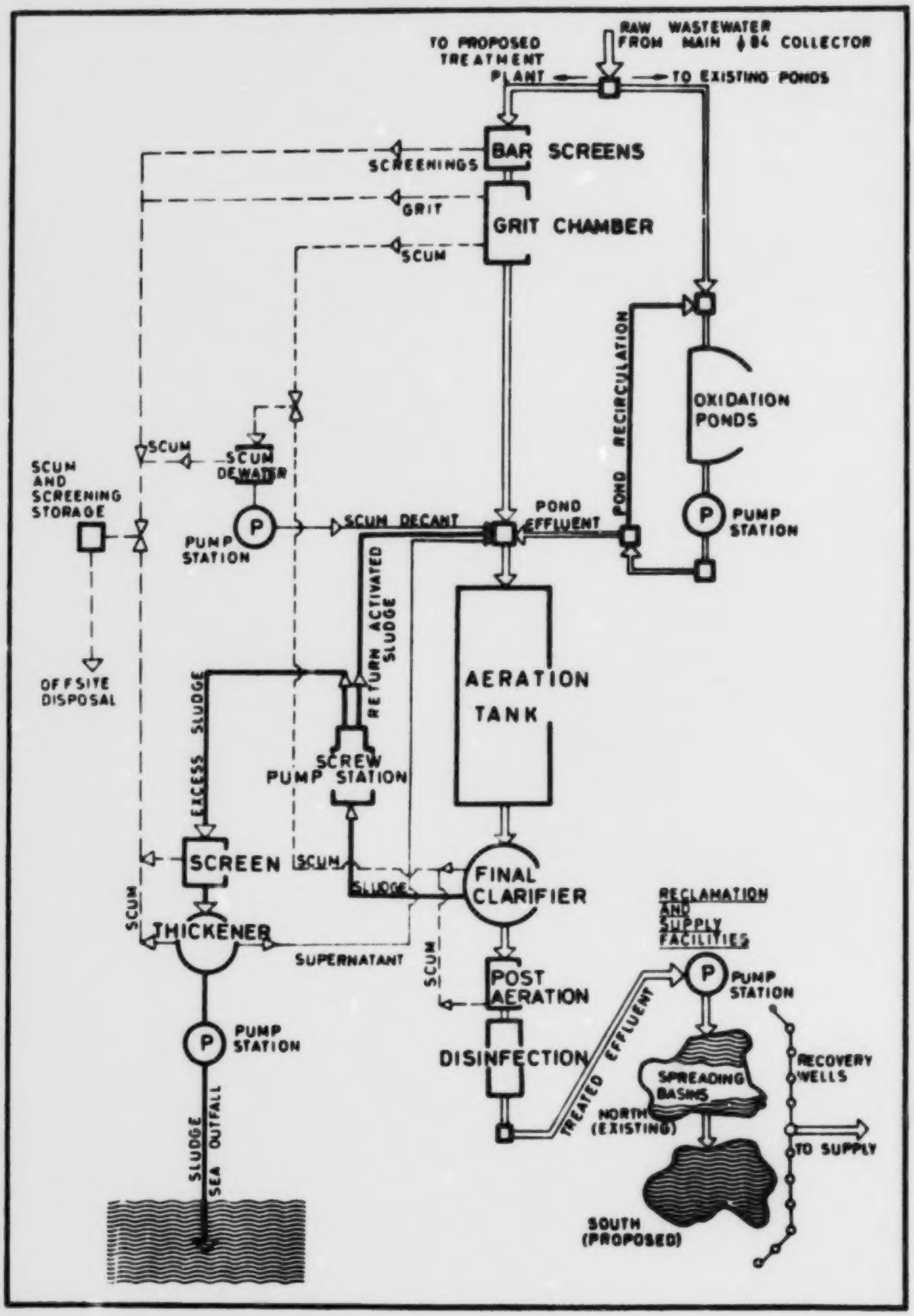
Despite the advanced stage of the project the designers have as yet made no final plans for the treatment of the reclaimed water for purposes of domestic consumption. The results of studies to evaluate the health aspects of reusing the effluent for potable purposes which have recently been initiated at the Hebrew University of Jerusalem will provide valuable guidance in determining the degree and form of additional treatment that will be required.

One of the questions facing the designers is whether to provide additional treatment for all the reclaimed water or only for the portion of it directed for municipal use. As presently designed the national water system supplying the south of the country is a fully integrated one which serves both agricultural and municipal consumers with the same quality water, all of which currently meets drinking water standards. The Dan Region Project's initial plans called for supplying reclaimed water directly to this system. This would dictate that all such water meet standards required for potable use. However, over 80% of the water is used in agriculture which could accept water of a lower chemical standard, but which has been adequately treated as far as enteric bacteria and viruses are concerned. The production of well disinfected wastewater for unrestricted agricultural use would be far less complicated and more economical than producing water for potable use.

The designers are presently considering the possibility of developing separate water supply system for utilizing reclaimed water from the Dan Project so that the major part could be used for agricultural and industrial purposes and only a portion, which would receive additional treatment, would be used for municipal and domestic purposes.

FIGURE Nº 2

DAN SEWAGE RECLAMATION PROJECT
SECOND STAGE (100 MCM/YEAR
SCHEMATIC LAYOUT



RAW WASTEWATER FROM MAIN ϕ84 COLLECTOR
TO PROPOSED TREATMENT PLANT
TO EXISTING PONDS
BAR SCREENS
SCREENINGS
GRIT
GRIT CHAMBER
SCUM
OXIDATION PONDS
POND RECIRCULATION
SCUM
SCUM DEWATER
SCUM AND SCREENING STORAGE
P
PUMP STATION
SCUM DECANT
POND EFFLUENT
P
PUMP STATION
OFFSITE DISPOSAL
RETURN ACTIVATED SLUDGE
AERATION TANK
EXCESS SLUDGE
SCREW PUMP STATION
SCREEN
SCUM
SLUDGE
FINAL CLARIFIER
SCUM
THICKENER
SUPERNATANT
SCUM
RECLAMATION AND SUPPLY FACILITIES
P
PUMP STATION
POST AERATION
TREATED EFFLUENT
RECOVERY WELLS
P
PUMP STATION
DISINFECTION
SPREADING BASINS
NORTH (EXISTING)
TO SUPPLY
SLUDGE SEA OUTFALL
SOUTH (PROPOSED)

The costs involved in developing such a separate supply system may be appreciable however. Another possible alternative is to use all of the reclaimed water for agricultural or industrial purposes, if it develops that meeting drinking water criteria makes the project economically unfeasible.

The project has been planned for development in two stages and has been described as follows by Amir and Idelovitch of Tahal (1):

First Stage

The first stage now in operation has a load of .041 MCM/day (10.3 MGD) and serves the southern suburbs of Tel Aviv as well as three neighboring towns. The treatment as now developed includes: biological purification in recirculated facultative oxidation ponds having an area of 120 hectares; chemical treatment by excess lime precipitation; ammonia stripping in open ponds; effluent stabilization in ponds and lime sludge disposal. The biological treatment ponds have been operated since 1970 while the chemical treatment and recharge of effluent is planned for the early part of 1975. A series of observation wells have been placed at varying distances between the ponds, recharge basins, and recovery wells so that the effects of percolation from the ponds and recharge basins on the quality of the water in the aquifer can be determined at various stages prior to the arrival of the recharged water at the recovery wells.

Second Stage

The second stage will have a capacity of .27 MCM/day (68.5 MGD) and will serve the whole area of the Dan Region. This stage is now in an advanced stage of planning (see Figure 2). The treatment includes: advanced biological purification by a modified low-rate activated sludge process which will provide for nitrification and denitrification, (the treatment in oxidation ponds will be partially abandoned in the second stage due to the large land area required); in-plant chemical precipitation; post aeration and disinfection of the effluent; and excess sludge disposal by means of a long sea outfall which will assure suitable dilution, dispersion and bacterial decay before reaching the shore line. Some existing ponds from the first stage will be integrated into the operation of the second stage treatment plant in order to reduce peak loads reaching the main plant, thus allowing for savings in capital and operating costs.

In the early stages of evaluating the quality of the reclaimed water from the Dan Project it becomes apparent that the concentration of nitrates would be several times greater than that recommended for drinking water. The facilities for excess lime precipitation and ammonia stripping in open ponds in the first stage and the nitrification/denitrification capacity of the low-rate activated sludge process in the second stage were designed specifically to

TABLE NO. 1: DAN SEWAGE RECLAMATION PROJECT - SECOND STAGE
VALUE OF MAJOR PARAMETERS IN WASTEWATER AND EFFLUENT (in mg/l)

	Raw wastewater	Plant effluent
BOD, mg/l	300-700	10-15
COD	600-1600	60-120
SS	350-500	10-20
Total N	70-100	10
NH_4/N + Org N	40-70	8
$(NO_3 + NO_2)$ N	0.5-1	2
Phosphates P	10-20	1.5
Chlorides	150-350	150-350
Dissolved Oxygen	-	4
Coliform per 100 ml	10^7-10^9	10-500

meet this problem. It is anticipated that the total nitrogen of the effluent before recharge will be under 10 ppm and that the reclaimed water will not deviate from accepted standards for nitrates.

The designers report that the anticipated main chemical characteristics of raw wastewater, the secondary effluent, and tertiary effluent prior to infiltration into the aquifer will be as shown in Table 1 (1). They also anticipate further improvement of the physical chemical and microbiological quality as a result of the slow sand filtration in the recharge basins and long period of residence, further filtration and dilution that occurs in the acquifer prior to recovery. They estimate that the recovered water, after further disinfection and dilution with good quality ground water will "met prevailing standards for drinking water quality"(1). However, here it must be stated that the W.H.O. has reported that meeting conventional standards for drinking water cannot be considered as adequate in the case of reclaimed wastewater for potable use (6). The health requirements involved should be much stricter since the water source under consideration may contain many of the toxic inorganic and organic chemicals found in municipal and industrial wastewater as well as their little studied breakdown products.

Estimated Costs

The designers estimated cost of producing the tertiary effluent in the second stage is $.70-.90/1000 gal while the additional cost of recharge and recovery is estimated at $.20-.30/1000 gals). The total cost of reclamation without the costs for additional treatment that will most likely be required to remove potentially toxic residual organics is thus estimated at $.90-1.20/1000 gals (1). It can be assumed that activated carbon treatment and ozonization will be required for that portion of the reclaimed water which will be supplied for domestic consumption, thus additional costs in the range of $0.15-0.25/1000 gals will have to be included. Although this is indeed costly, the only alternative water source for cost comparison purposes is desalinated seawater which is now estimated to cost about $4-5/1000 gals.

EVALUATION OF HEALTH EFFECTS OF RECLAIMED WASTEWATER - GENERAL APPROACH

The approach to evaluating the health effects of reusing wastewater for potable purposes in Israel recommended by the author to the health and water authorities in Israel has been fully detailed in a previous paper (7) and follows the general approached presented in the W.H.O. report on health safeguards in the reuse of effluents of 1973 (6). This approach has been further refined in the report of the International Working Meeting on the Health Effects Relating to Direct and Indirect Reuse of Wastewater for Human Consumption (8) held in Amsterdam in January 1975.

This approach is based on the premise that conventional drinking water standards are not considered as providing an adequate basis for the health evaluation of reclaimed wastewater to be used for potable purposes. These standards do not usually include maximum allowable concentrations for the hundreds of potentially toxic organics which can appear in urban and industrial wastewater. Also, such standards cannot as yet cope with the problem of the little known breakdown products resulting from biological degradation or from chemical reactions that occur as a result of treatment. The formation of carcinogenic organohalides by chlorination of water contaminated with organics is just one illustration of the complexity of the problem (9). Recent surveys of organics in polluted river water, wastewater effluent and finished drinking water carried out in Europe and the United States have detected as many as 1000 different organic compounds. Many of these have known toxic effects while little or nothing is known about the possible chronic effects of hundreds of these compounds (8). Although it is hoped that one day there will be adequate toxicological data to allow for the establishment of specific standards for each one of the hundreds of chemicals that could appear at times in renovated water, this is felt to be an impractical goal for the near future.

Therefore, the Amsterdam report (8) recommended that an essential precondition for any reuse of wastewater for domestic consumption is the control of industrial wastes to the maximum degree so as to remove at source as many potentially toxic chemicals as possible. They also recommended ". . .that to the extent that it is feasible, industrial effluents should be totally diverted from the reuse system."

The report further recommended "that at this stage with the tremendous gap in knowledge concerning the toxic effects associated with organic components in renovated water, the most prudent policy would be to provide for the optimal removal of total organic carbon to the lowest feasible level." They set as a tentative goal "less than 5 ppm of TOC".

Our approach, and that recommended by the W.H.O. recognizes that it is not possible to fully evaluate the possible toxicological effects of renovated water based on a study of specific chemical constituents. The W.H.O. therefore recommends (6) "that the complete and proper toxicological evaluation should be made using the actual finished water intended for human consumption with its real mixture of residual chemicals (and concentrates of them) remaining after treatment. Long term feeding experiments with more than one species of experimental animals may be required as well as other toxicological evaluation tests."

The first essential step in carrying out the toxicological evaluation of the real mixture of residual chemicals is to develop an appropriate technique for concentrating these organics from the final effluent planned for reuse. It is essential to obtain concentrates of these chemicals 10-100 times those found in the renovated water itself for proper chronic toxicity studies with animals. Standard procedures in chronic exposure experiments require feeding animals with concentrations many fold greater than proposed for actual use. This safety factor is essential in order to detect any detrimental effects that may appear only in particularly susceptible elements in the normal population which usually includes the aged, the infirm, infants and pregnant women. It is also not possible to expose animal colonies equivalent in size to the actual population groups of hundreds of thousands that may be exposed to renovated wastewater. For these reasons, reliable methods for concentrating the organics in wastewater are required. These methods must not lead to a change in chemical composition or effect the integrity of the organic components while avoiding the loss of essential fractions.

It has been estimated that for a two year chronic study with 300 rats, which we are planning, it will be necessary to process some 500 cubic meters of water if a concentration factor of 100 is to be achieved. We have initiated preliminary studies for concentrating organics to meet the above criteria using adsorption/desorption and ultrafiltration membrane processes but to date find a significant loss of organics takes place. The E.P.A. Water Supply Research Laboratory in Cincinnati has made considerable progress toward solving these problems. Our planned testing program of reclaimed water from the Dan Region Project includes sub chronic (90 day) and chronic (2 years) tests with rats with various concentrates up to 100 times. We will also process the water with activated carbon alone and in combination with ozonation to achieve the lowest feasible level of total organic carbon. Tests for carcinogenicity, teratogenicity and mutagenicity will be made as well as tests on fertility. A 3-5 year period is required for such a program of studies.

Preliminary tests of water drawn from an observation well 50 meters from the existing oxidation ponds indicate a TOC of 10 in the ground water which according to its salinity appears to be about 75% wastewater effluent and 25% groundwater. The pond effluent itself has a TOC of 40 ppm. These very tentative preliminary findings indicate that some of the residual organics do indeed pass through the sandy aquifer. If these findings hold true for the final project working under somewhat more favorable conditions, they may indicate that additional treatment to remove organics will be required. Another indication of this is the concentration of A.B.S. in the reclaimed water of 5 ppm as compared to 13.6 ppm in the pond effluent. Hard detergents are still used in Israel.

MICROBIAL QUALITY

One of the earliest concerns in wastewater reuse for potable purposes has been the risk of pathogenic bacteria and viruses passing through the system. There has been particular concern about viruses since it has been demonstrated that they are under certain conditions many times more resistent than bacteria to natural inactivation and various water and wastewater treatment processes. Another reason for the special concern about the virus risk has been the evidence that very small numbers of viruses can be infectious to man.

In order to assure the safety of reclaimed water for potable use it is essential to develop reliable monitoring methods to check for the presence of viruses in very large volumes of water. Various authorities have suggested that anywhere between 100-1000 gals of water need be tested for viruses in renovated water. A number of potential methods for carrying out such tests are under development (10). The planners of the Dan Project are fully aware of the need to monitor the reclaimed water for bacteria and viral pollution and have initiated such programs.

We are currently working on evaluating the effectiveness of various virus monitoring techniques in order to select the most effective one for large volumes of renovated water.

A prudent monitoring policy should provide for completion of microbial testing including virus assay before supplying the water to the public. Dr. E. Katzenelson of our laboratory is presently developing a very rapid virus monitoring technique using fluorescent antibodies which can provide a qualitative answer in 9 hours and a quantitative assay in 24 hours. Such a technique will be particularly vital in monitoring reuse projects which allow for only limited hold-up time of the final effluent.

Monitoring

Assuming that after a full toxicological evaluation of the final treatment train the reclaimed water is found to be acceptable for human consumption, it will still be necessary to establish a special monitoring program to assure that water of a consistantly safe quality will be supplied to the public.

In the case of the Dan Region Project this is facilitated by the series of observation wells located between the recharge basins and the recovery wells. It will be possible to withdraw water at regular intervals and to determine any changes in quality of the reclaimed water months before it reaches the recovery wells. In addition to bacteriological and virological tests and analysis for known inorganic and organic toxic chemicals, it will be essential to develop rapid toxicological bioassays. A number of promising methods using bacteria, cell cultures and fish are under development and may become available to meet this method.

The approach to monitoring reclaimed wastewater for potable purposes must be stricter than that currently applied to drinking water and should require the completion of all microbiological, chemical and toxicological assays prior to the release of the water to the public. In the case of the Dan Project, this is quite feasible, but for projects that do not include long term storage in the ground water special holding tank facilities would be required.

Conclusion

Wastewater reuse has received a very high priority in the national water resources development plans of Israel due to the severe shortage of water facing the country. The Dan Region Water Reclamation Project in aiming to supply renovated water for potable consumption will have to meet the most rigorous tests to assure that the final product will have no detrimental effects on human health. Detailed chemical analysis and a full toxicological evaluation of possible chronic effects is being initiated as well as a rigorous bacterial and viral testing program. The adequacy of the final treatment train in removing pathogens and potentially toxic organics is yet to be determined. However, the Dan Project has a valuable built-in safety factor in its use of recharge and long term underground storage which facilitate stringent monitoring and control programs.

The results of these vital studies will enable the health authorities to determine the suitability of the reclaimed water for potable use.

Acknowledgement:

We wish to thank Mr. Y. Amir and Mr. E. Idelovitch of Tahal-Consulting Engineers Ltd., Tel Aviv for the use of figures 1 and 2 and the other valuable data on the Dan Region Water Reclamation Project.

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APPENDIX

RESEARCH NEEDS: EVALUATION OF THE HEALTH ASPECTS OF REUSING WASTEWATER FOR POTABLE PURPOSES

Prepared by: H.I. Shuval

A. General Recommendations

1. Since individual municipalities, regions or even national reuse projects in smaller countries will not normally be in a position to carry out the full spectrum of required studies to evaluate the health aspects of reusing wastewater for potable purposes and since the results of such studies will be of universal value, it is essential that major research support be provided by the Federal Government in the United States, research foundations and the United Nations agencies.

2. Such studies should be carried out in an international coordinated program so that the maximum amount of information be mustered from varying sources to meet the vital research needs of all bodies concerned.

3. An international scientific coordinating group should be established to further the above objectives.

B. Specific Recommendations

1. Methods must be developed to effectively concentrate organics in large volumes of wastewater effluent so as to provide material for chronic animal exposure tests. Concentrates of at least 100 times should be obtainable, which maintain the integrity of the chemical components, do not change the relative concentrations and do not lead to the loss of essential fractions.

2. Refined screening assays for categories of organic compounds of potential toxic importance should be developed to replace gross tests for organics such as C.O.D., C.C.E. and T.O.C.

3. Reliable tests for the rapid detection of low concentrations of viruses in large volumes of water (as much as 1000 gals) should be developed and standardized.

4. Chronic toxicological studies should be carried out on as great a number as possible of the organic refractories of suspected toxic importance detected in wastewater streams so as to provide a rational basis for evaluating the risks involved in the presence of such compounds in reclaimed water for potable use. Where possible, maximum allowable concentrations for drinking water should be established.

5. Rapid bioassay methods should be developed to allow for the routine toxicological monitoring of reclaimed wastewater destined for potable use.

6. Retrospective and prospective epidemiological studies should be carried out on population groups exposed to heavy polluted surface waters supplies (in direct wastewater reuse) so as to determine if there are detectible detrimental health effects. These studies should be international in character but should follow carefully predetermined research criteria so as to assure comparability.

7. A carefully designed protocol for chronic animal exposure experiments with reclaimed wastewater (and concentrates of the same water) should be prepared and pretested which could serve as a guide for the various testing programs for different wastewater reuse projects. Then a coordinated series of programs should be initiated with all results being provided to the parties concerned. Various advanced wastewater treatment systems for water reclamation could thus be evaluated on a comparable basis.

DISCUSSION

QUESTION: Mr. Charles W. Lee, Washington University Medical School, St. Louis, Missouri. I am interested in the vasodilation effect that you observed in feeding nitrates to the rats. Would you care to comment as to what chemical form of nitrate you actually gave these animals? And was there a corresponding blood pressure lowering effect that was recorded with the vasodilation?

RESPONSE: Prof. Shuval. We administered both sodium nitrite and sodium nitrate in drinking water to rats over an 18 month period and the effect of dilation of heart blood vessels was detected for both chemicals. We did not check the blood pressure of the rats although I agree that it is an interesting question worth looking into. Although the toxicological importance to humans in this finding is not yet clear, it does add further weight to the case against relaxing the nitrate standards in drinking water until we know more about the possible chronic effects on man. We have submitted our full report on this to the EPA.

QUESTION: Mr. Jack Glennon, U.S. Army Medical Research Development Command, Washington, D.C. Two of your comments sort of got me a little concerned and also surprised. I anticipated that you would probably get a large loss of water due to infiltration and evaporation in the oxidation pond process. Do you have any plans in mind to close the loop for the direct recycle: in other words, there may be a higher return for the water?

The second question. I was a little surprised to see your plant dispose of the sludge at sea with the option to at least stabilize the sand-dune areas and this sort of thing. Are there any plans to turn that around?

RESPONSE: Prof. Shuval. As to the first question of water loss, yes, there will be some water loss due to evaporation and infiltration. The replacement of ponds by activated sludge in the second stage will reduce evaporation; but we do need long-term storage facilities and balancing of the flow, and feel that groundwater recharge is worth the price.

The Dan Project includes a series of monitoring wells from the recharge point to the pickup point whereby we can monitor the quality of the water continuously months before we have to use it. We feel that that type of protective buffer is well worth the investment.

As for sludge disposal, I am not in a position to debate it. I am not particularly in favor of sea disposal, but that is what the designers are proposing. I would say that there are other alternatives, such as land disposal and sludge utilization.

HEALTH ASPECTS OF REUSING WASTEWATER FOR POTABLE PURPOSES - SOUTH AFRICAN EXPERIENCE

E.M. Nupen and W.H.J. Hattingh
National Institute for Water Research of the Council for Scientific and Industrial Research
P.O. Box 395, Pretoria 0001, Republic of South Africa

ABSTRACT

In studies on the health affects of the reuse of municipal wastewaters, drinking water supplies and their sources were analysed for a wide range of chemical and microbiological quality parameters. Studies were also done to determine possible health effects not covered by these parameters. Potable waters derived from advanced reclamation processes were also included. Results presented are those obtained during the first two years of a ten year study. All the drinking water supplies tested conformed to international quality criteria. Organic material extracted from drinking waters had no adverse effects on the health of laboratory animals. The quality of reclaimed drinking water was better than that of many supplies derived from surface sources. Consumption of reclaimed water had no detectable effect on the incidence or epidemiology of diseases in the community. Contemplated studies aimed at analysing drinking waters in greater detail for possible adverse health effects and current research needs are discussed.

INTRODUCTION

Southern Africa will not have enough fresh water resources by the year 2000. Already one city in the area has had to resort to the reclamation of municipal wastewater to augment its potable supplies. Similar reclamation systems are foreseen in many other developing areas where population growth will outstrip water supply. More than 60 per cent of the water supplied to a city becomes wastewater which is treated in sewage purification plants before being discharged into natural drainage systems. There is therefore a rapid, ever-increasing volume of treated sewage effluent polluting the natural water resources. Simultaneously the complexity and variety of the pollutants present in these effluents are also increasing, as new chemical products become available to meet the present-day technological development.

Pollutants dangerous to public health in municipal wastewater, range from chemicals such as carcinogens and heavy metals, to pathogenic microorganisms. There is a paucity of knowledge of the occurrence of many of these pollutants in surface waters, sewage and sewage works effluent and of their possible effects upon man. Long-term consumption of water containing pollutants, might produce chronic or perhaps acute disease with resultant grave economic implications. Existing water purification plants may not be equipped to meet these rapidly changing conditions. On the other hand, the efficiency of reclamation plants treating municipal wastewaters for reuse, has been intensively studied for the successful removal of many pollutants (1-10), yet the possible effects of the introduction of such reclaimed wastewater on the health of the receiving community must be assessed.

Much time and thought have gone into the consideration of these questions. Can the impact of the introduction of reclaimed water be measured in terms of epidemiological patterns? How great are the health hazards involved? What about infectious hepatitis - carcinogens - shock loads of toxic wastes - heavy metals? In our search for answers, we found that these same questions applied to all drinking water supplies.

Epidemiological studies have proved unreliable for the assessment of many health aspects related to drinking waters because of difficulties in data collection, and as it is only when gross pollution occurs, that the effect of toxic or disease producing pollutants can be measured by their obvious reaction in the community; micropollutants responsible for long-term health effects or the production of infection without obvious disease patterns are not detected. Therefore an in-depth study of the quality of water supplies to a community, will give the greatest information regarding the safety of the health of that community in relation to its drinking water supply.

A programme was therefore evolved and is being conducted, to determine the health aspects of reclaimed wastewaters, by the collection of information on the type and quality of the constituents in municipal wastewaters, reclaimed wastewaters and other waters, using chemical, microbiological, cytotoxicological, bio-assaying, immunological and epidemiological techniques. This data forms a base line on which variations in the quality of reclaimed and other waters are measured, now and in the future, so that the health of the receiving communities may be protected.

SURVEILLANCE PROGRAMME

A ten year water quality surveillance programme commenced in 1973 in two areas of Southern Africa. In area A, reclaimed municipal wastewater periodically augments the drinking waters obtained from a series of boreholes and from three dams. The municipal wastewater which is reused is of purely domestic origin.

In area B, a treated river water, which supplies the largest population density in the country, is augmented by a treated dam water, a chlorinated spring water, a borehole water and chlorinated and unchlorinated fountain waters. The river water before treatment receives effluent from several sewage purification plants and surface runoff from a densely populated and industrialised area. An experimental 4.5 Mℓ/d reclamation plant, which treats mixed domestic and industrial wastewaters, is also situated in this area.

The safety of the waters in these two areas for potable use will be evaluated by the interpretation of data obtained from:

(a) The chemical and microbiological qualities of the waters.

(b) The use of cell culture systems to test the water for possible cytotoxicity.

(c) An investigation into the possibility of the spread of R^+ bacteria by polluted waters.

(d) The determination of long-term effects of possible pollutants by means of the bio-assaying of different waters using experimental animals such as rats, mice, fish, dogs and primates.

(e) A limited epidemiological survey in area A.

(f) Virus and serum banks of specimens collected in (a) and (e) which may be used for retrospective immunological studies, if necessary.

Chemical and microbiological analytical procedures

Viruses which may be present in the water environment are well documented (9, 11-13). It is possible that other viral enteric pathogens such as those recently isolated by Bishop *et al*. (14), Paver *et al*. (15) and Kapikian (16) may also be transmissible by water. For the purpose of this study, poliovirus strains, coxsackie viruses which can be isolated in tissue cultures, enteroviruses and adenoviruses (over 100 strains in all) are used to determine virus pollution.

Evaluations for total vegetative bacteria, coliform organisms, presumptive and confirmed *E. coli* I, *Ps. aeruginosa*, *Cl. perfringens* and *Staphylococcus aureus* and viruses were done as previously described (1,2,17-19). Small numbers of parasite ova (*Ascaris* spp., *Taenia* spp., *Trichuris trichuria* and various species of hookworm) were concentrated from large volumes of water by the same ultrafiltration method described for viruses.

Chemical evaluations for parameters shown in Table 1 were based on published methods (20) many of which have been automated. The inorganic constituents are well defined (see Table 2) but analytical techniques for the characterisation and evaluation of organic materials are mostly undeveloped. Such material exists in small concentrations in water (about 1 to 5 mg C/ℓ). Before this material can be identified, it must first be concentrated and extracted *without any*

TABLE 1. CHEMICAL QUALITY OF SOME OF THE TREATED DRINKING WATERS. AREA A.

		Treated dam water III						Borehole water I				Borehole water II			
		1971/72		1973		1974		1973		1974		1973		1974	
		Min/max.	Aver.	Min/max.	Aver.	Min/max.	Aver.	Min/max.	Aver.	Min/max.	Aver.	Min/max.	Aver.	Min/max.	Aver.
	pH	7,2-8,4	-	7,6-8,2	-	7,7-8,0	-	7,8-8,3	-	8,0-8,2	-	7,6-8,5	-	7,7-8,3	-
	Conductivity (umho/cm)	230-370	290	323-358	337	223-372	340	270-662	521	629-672	650	623-1055	826	279-1120	860
mg/ℓ	Total alkalinity ($CaCO_3$)	69-154	92	58-109	83	64-78	72	83-220	174	178-248	212	256-305	284	41-415	159
	Chemical oxygen demand	9-54	19	28-43	37	19-35	30	18-27	22	24-147	56	14-29	22	20-340	94
	MBAS (Manoxol OT)	<0,1-0,7	0,2	0,2-0,7	0,5	<0,1-0,3	0,3	<0,1-1,0	0,4	<0,1-0,6	0,2	<0,1-0,6	0,3	0,1-0,7	0,4
	NH_3-N (N)	0-0,5	0,2	<0,2-0,4	0,3	0,3-0,4	0,3	<0,2-0,3	0,2	0,2-0,3	0,3	<0,2-0,4	0,3	<0,2-0,3	0,3
	Organic-N (N)	0-1,1	0,4	0,5-1,2	0,8	0,4-1,0	0,8	0,6-1,0	0,5	0,3-0,6	0,5	<0,2-2,1	0,8	0,3-2,0	1,0
	NO_2-N (N)	0-0,3	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
	NO_3-N (N)	0,2-1,0	0,4	<0,2-0,8	0,5	0,6-1,1	0,8	0,2-0,9	0,5	<0,2-0,9	0,4	<0,2-0,9	0,4	0,2-1,6	0,7
	Orto-P (P)	0-0,2	0,1	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2-0,3	0,3	<0,2	<0,2	<0,2	0,2
	Organic-P (P)	0-0,5	0,2	<0,2-0,7	0,4	<0,2-0,4	0,3	<0,2-1,9	1,1	<0,2-1,6	0,9	<0,2-1,0	0,6	0,2-0,8	0,4
	Inorganic-P (C)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Organic-C (C)	1-28	8	20-24	21	6-15	11	18-28	24	3-16	9	23-35	31	3-40	17
mg/ℓ	Sodium (Na)	11-24	17	16-17	17	12-23	18	5-25	18	24-35	27	70-141	97	1-164	51
	Potassium (K)	5-8	7	9-11	10	5-6	5	6-9	8	6-9	7	14-18	16	8-20	12
	Calcium (Ca)	36-49	42	33-44	37	30-51	37	42-68	56	63-70	66	53-65	59	40-68	54
	Magnesium (Mg)	4-6	5	5	5	3-4	3	6-27	20	26-28	27	14-21	18	1-23	8
	Chloride (Cl^-)	13-33	24	18-30	23	18-20	19	4-8	6	5-7	7	12-38	23	10-50	34
	Sulphate (SO_4^{2-})	26-60	38	27-63	42	28-77	44	11-103	51	99-126	106	72-149	109	44-152	82
	Fluoride (F^-)	<0,1-0,3	0,2	0,3-0,4	0,3	0,1-0,3	0,2	0,2-0,4	0,3	0,2-0,4	0,3	0,4-0,9	0,7	0-0,8	0,4
	Silica (Si)	0,4-3,0	0,9	0,2-0,5	0,3	1,5-2,0	2,0	3-35	20	31-52	38	20-44	29	0,5-47	18
µg/ℓ	Silver (Ag)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Arsine (As)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barium (Ba)	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
	Cyanide (CN^-)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Aluminium (Al)	<100-100	100	<100-1300	867	123-627	377	<100	<100	<100	<100	<100	<100	63	63
	Boron (B)	<100-200	100	<100	<100	<100	<100	<100	<100	<100	<100	<100-360	193	320	320
	Beryllium (Be)	<5	<5	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
	Cadmium (Cd)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Cobalt (Co)	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Chrome (Cr)	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Copper (Cu)	8-75	23	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Mercury (Hg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Iron (Fe)	<25-151	67	<25	<25	26-49	38	<25	<25	52-66	59	<25-160	74	69-80	73
	Manganese (Mn)	<25-30	<25	<25	<25	<25	<25	<25	<25	85	85	<25-32	30	207	207
	Nickel (Ni)	<25-40	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Lead (Pb)	6-122	27	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Strontium (Sr)	59-144	92	<25-140	60	60-150	108	80-130	104	140-210	182	30-400	253	50-450	230
	Zinc (Zn)	<25-53	25	<25	<25	27-42	35	<25-100	64	40-195	109	<25-76	42	33-50	42
	Selenium (Se)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: All commas in tables denote decimal points.

alteration in its molecular structure as molecular structure defines the toxicity of a particular compound. No single method will suffice and multiple chemical analyses are necessary to cover the wide range of pollutants which may be present in water. The following methods have shown promise:

(a) Adsorption onto activated carbon and subsequent recovery of organic material with solvents such as chloroform and methanol. The suggestions put forward by Middleton and his co-workers at the EPA, Cincinnati are followed.

(b) Counter-current distribution analysis is done using an automated Graig apparatus. Some of the inherent shortcomings of the activated carbon method are eliminated.

(c) Preparation of a benzene extract by using a blender such as an Ultra Turrax. The benzene is then reduced to a small volume in a rotary evaporator and finally concentrated in a Kuderna-Danish evaporator to a volume of 10 to 50 µℓ. This extract may then be used to test for carcinogens by thin layer chromatography (21).

(d) A number of analytical techniques for the isolation and characterisation of organic matter are being developed, meanwhile the technique of finger printing is used to compile an archive of data which may be used for retrospective studies. Finger printing includes the plotting of ultraviolet, infra-red and fluorescence spectra of the isolated organic material.

(e) A gas chromatograph/mass spectrometer (GC/MS) combination is used in the analytical determinations, and programmes for data storage and computer processing are being developed to reduce the time required for processing the data. A benzene extract (prepared as before) is injected into the GC (4% Dexil 400 on

TABLE 2. DRINKING WATER CRITERIA FOR CHEMICALS WHICH MIGHT AFFECT PUBLIC HEALTH, AS LAID DOWN BY THE WORLD HEALTH ORGANIZATION (WHO), USA PUBLIC HEALTH SERVICES (USPHS), SOUTH AFRICAN BUREAU OF STANDARDS (SABS) AND RUSSIA (USSR). All concentrations are expressed as µg/ℓ unless otherwise stated

Constituent	Quality criteria laid down by				
	W H O		USPHS (1962)	SABS (1971)	USSR (1970)
	International norms (1971)	European norms (1970)			
Arsenic	50	50	10	50	50
Barium	N.S.	1 000	1 000	N.S.	4 000
Beryllium	N.S.	N.S.	N.S.	N.S.	0,2
Cadmium	10	10	10	50	10
Chromium (hexavalent)	N.S.	50	50	50	100
Cobalt	N.S.	N.S.	N.S.	N.S.	1 000
Copper	50	50	1 000	1 000	100
Cyanide	50	50	10	10	100
Carbon chloroform extractables (CCE)	N.S.	200-500	200	N.S.	N.S.
Hydrogen sulphide	N.S.	50	N.S.	N.S.	nil
Lead	100	100	50	50	100
Mercury (total)	1	N.S.	N.S.	N.S.	5*
Nickel	N.S.	N.S.	N.S.	N.S.	100
Phenol compounds	1	1	1	1	1
Selenium	10	10	10	N.S.	1^{+}
Strontium	N.S.	N.S.	N.S.	N.S.	2 000
Zinc	5 000	5 000	5 000	5 000	1 000
Silver	N.S.	N.S.	50	N.S.	
Nitrate (NO_3) mg/ℓ	45	<50	45	10 as N	10 as N
Fluoride mg/ℓ	0,6-1,7	0,7-1,7	0,6-1,7	1,0-1,5	1,5
Bacteria	N.S.	nil/100 mℓ	N.S.	nil/100 mℓ	N.S.
Viruses	N.S.	nil/ℓ on testing of 10 ℓ	N.S.	N.S.	N.S.

N.S. = Not specified
* = For organic compounds
+ = As $SeO_3^{=}$

chromosorb G, acid washed, 80 to 100 mesh at 100 °C) and the temperature is then programmed from 100 °C to 310 °C at a rate of 2 °C/min. The mass spectra are obtained simultaneously.

(f) Hexane extraction is used to determine chlorine, sulphur, phosphorus and nitrogen-containing pesticides by means of gas chromatography.

(g) Molecular mass distribution patterns are determined by consecutive filtration through molecular membranes. Organic molecules are divided into the following five mass groups: more than 100 000, 10 000 to 100 000, 1 000 to 10 000, 500 to 1 000 and less than 500.

With the techniques described, a number of different carcinogens have been identified from waters by thin-layer chromatography (Table 3). Mole mass distribution studies have shown promise in evaluating the mole mass distribution of the total organic loading of various types of waters. Numerous extracts have been prepared and are at present under investigation by GC/MS.

TABLE 3. KNOWN ORGANIC CARBONS IDENTIFIED IN HUMUS TANK EFFLUENT (HTE), TAP WATER (TW) AND RECLAIMED WATER (RW)

Compounds tested for	TW	HTE	RW
3 methylpyrene	+	+	+
3,4 benzopyrene	+	+	-
22 methylcholanthrene	+	+	-
perylene	+	+	-
fluoranthene	+	+	+
9,10 benzophenanthrene (triphenylene)	-	-	-
1,2,5,6 dibenzanthracene	-	-	-
1,2,3,4 dibenzanthracene	-	-	-
coronene	-	-	-

+ = present
- = absent

Quality surveillance of municipal wastewater

The South African standards for the discharge of purified sewage and industrial effluents are summarised in Table 4, with the addendum that no other constituent is allowed which may be harmful or poisonous to man, other animals, fish or other water life, or is detrimental to agriculture. These parameters were used for evaluating the efficiency of representative sewage treatment works in the areas under observation.

Area A

A sewage works treating domestic wastes has been under intensive microbiological monitoring for the past five years, as its effluent is directly reclaimed for potable use. The yearly averages of the bacterial and viral counts of the raw sewage entering the plant are higher than in the other works studied. These averages are reduced by 1 to 2 log units during biological filtration and secondary settling (3). Further treatment of the humus tank effluent through a series of maturation ponds reduces the microbiological counts to well within the limits for safe discharge into receiving waters. The chemical quality of the maturation pond effluent is also good, especially with regard to ammonia and phosphate levels.

The judicious exclusion of industrial wastes ensures the required standard of the works effluent for discharge into receiving waters.

Area B

The testing of a sewage works in this area, receiving a large amount of industrial wastes was ideal for the evaluation of

TABLE 4. THE GENERAL STANDARDS FOR TREATED INDUSTRIAL EFFLUENTS AS GAZETTED BY THE S.A. GOVERNMENT R533 (1962). (Concentrations in mg/ℓ unless otherwise stated.

Parameter		Limit
pH		5,5 to 9,5
Dissolved oxygen		At least 75% of saturation point
E. coli (faecal)/100 mℓ		nil
Temperature		35 °C
Chemical oxygen demand		75
Oxygen demand		10
Total dissolved solids		500 above intake water
Suspended solids		25
Sodium	(as N)	50 increase
Soap, oil and fats		2,5
Residual chlorine	(as Cl)	0,1
Free ammonia	(as N)	10,0
Arsenic	(as As)	0,5
Boron	(as B)	1,0
Hexavalent chromium	(as Cr)	0,05
Total chromium	(as Cr)	0,5
Copper	(as Cu)	1,0
Phenolic compounds	(as phenol)	0,1
Lead	(as Pb)	1,0
Cyanide	(as Cn)	0,5
Sulphide	(as S)	1,0
Fluorine	(as F)	1,0
Zinc	(as Zn)	5,0

possible chemical pollutants which may result from industry. The industrial effluent is delivered to the sewage works via a separate pipe line and is mixed with the domestic sewage on site.

During 1973/1974 loadings of cyanide, boron, iron, manganese, nickle and zinc were constantly high, but many of these metals were reduced to the required low levels in the finally treated effluent by sedimentation and dilution. The industrial effluent showed variations in pH values of between 2.8 and 8.3. Nevertheless the effect of the mixing of this effluent with domestic wastes stabilised the pH levels in the humus tank effluent to within normal limits. The inclusion of industrial effluents in municipal wastewaters increased the chemical loading to the sewage purification plant. The microbiological testing of this works will commence during 1975.

The purified effluent from another sewage works in this area, receiving half industrial and half domestic wastes, is used as an influent to an experimental reclamation plant. This effluent conformed to the normal limits required for chemical discharge (Table 4). Although the microbiological load of the raw sewage was less than that of a purely domestic waste, the effluent did not conform to the required bacterial standard for discharge into a receiving water. The effluent (after concentration for virus evaluation) showed cytotoxicity to monkey kidney cells.

A third sewage works with a low industrial loading was studied for 52 weeks during 1972/73. The concentrations of heavy metals entering the plant were low and the humus tank effluent was of a good chemical quality. This effluent is further treated in a series of maturation ponds which ensures that the final effluent is of a high standard before discharge into the receiving stream.

Quality surveillance of drinking waters and their raw water sources

As the quality of a drinking water is evaluated by its physical, chemical and microbiological constituents, it is worthwhile considering some of the safety parameters used at the present time (Tables 2 and 5). Although not a gazetted standard, no virus isolated per litre on the testing of 10 ℓ of sample is used as a safety parameter for drinking waters in South Africa.

Area A

The surveillance of the drinking water supplies to area A has been in progress for the last five years, and an enormous amount of data has been collected. An example of such chemical data collected on a treated dam water and on two borehole waters is shown in Table 1. The breakdown of this type of data is illustrated in Figure 1. With such surveillance small and significant changes in the quality of the drinking water in question can be detected and followed up.

The same technique applies in the weekly microbiological analyses as shown in Figure 2. For example, the microbiological loading was high in the raw dam water source (MP5) of the treated drinking water (MP8a). Evidence of faecal contamination in the treated drinking water as shown by the presence of *E. coli* occurred during 1974 and, of more significance, the recovery

TABLE 5. A SUMMARY OF PROPOSED CRITERIA FOR DRINKING WATER PREPARED FROM RELATIVELY UNPOLLUTED SOURCES (WATER QUALITY CRITERIA, 1972)

Composition	Limit	Comments
Alkalinity	N.S.	No recommendation, alkalinity associated with pH and hardness, rapid changes must be avoided.
Ammonia-N	0,5 mg/ℓ	Indicates pollution, influences chlorination.
Arsenic (total)	0,1 mg/ℓ	Adverse physiological effects.
Bacteria		
Faecal coliforms Total coliforms	2000/100 mℓ 20 000/100 mℓ	Geometric mean of bacteria may not exceed these limits in the raw water to be treated.
Barium	1 mg/ℓ	Adverse physiological effects.
Boron	N.S.	Harmful to plants, no knowledge of effect on humans.
Cadmium	0,01 mg/ℓ	Adverse physiological effects.
Chloride	250 mg/ℓ	Solely based on taste.
Chromium	0,05 mg/ℓ	Harmful effects not yet demonstrated.
Colour	75	An aesthetic norm, is measured in PtCo units.
Copper	1 mg/ℓ	Results in taste and odour effects.
Cyanide	1 mg/ℓ	Toxic to fish. No effect on man in small doses.
Dissolved oxygen	N.S.	Recommended to be as large as possible.
Fluoride	1,4-2,4 mg/ℓ	Based on temperature of water.
Detergents	0,5 mg/ℓ	Aesthetic norm expressed as methylene blue active substances (MBAS).
Hardness	N.S.	Depends on public acceptance.
Iron	0,3 mg/ℓ	Public acceptance, norm depends on dissolved Fe⁺⁺.
Lead	0,05 mg/ℓ	Toxic to man.
Manganese	0,05 mg/ℓ	Aesthetic norm.
Mercury	0,002 mg/ℓ	Toxic to man.
Nitrate-N	10 mg/ℓ	Adverse effects on man.
Nitrite-N	1 mg/ℓ	Adverse effects on man.
Odour	N.S.	Aesthetic norm.
Oil and grease	-	Water should not contain oil or grease.
Organic material		
CCE	0,3 mg/ℓ	Organic material adsorbed on activated carbon and extracted with chloroform.
CAE	1,5 mg/ℓ	Organic material adsorbed on activated carbon and extracted with ethanol.
Pesticides (halogens)	0,1-1000 µg/ℓ	Containing halogens have varying toxicities.
" (organic-P and carbonates)	100 µg/ℓ	Total concentrations may not exceed 0,1 mg/ℓ.
" (chlorophenoxy weedkillers)	2-100 µg/ℓ	Weedkillers like 2,4D may not exceed 0,1 mg/ℓ.
pH	6,5 to 9,0	
Phenolic compounds	1 µg/ℓ	Causes taste problems.
Phosphate	N.S.	Relationship between phosphates, biological productivity, taste and filtration is complex.
Phthalic esters	-	Potentially dangerous, little available information.
Polychlorinated biphenyl (PCB)	N.S.	Little available information.
Selenium	10 µg/ℓ	Toxicological information very scarce.
Silver	N.S.	Silver hardly ever occurs in more than 1 µg/ℓ.
Sulphate	250 mg/ℓ	Influences taste and has laxative properties.
Temperature	N.S.	Temperature must remain within aesthetic limits.
Total dissolved salts	N.S.	Limit is dictated by local conditions.
Turbidity	N.S.	Low turbidities are essential for the effective disinfection of drinking waters.
Viruses	N.S.	Methods available for the complete recovery of virus from more than 10 ℓ of water.
Zinc	5 mg/ℓ	Taste problems.

N.S. = Not specified

of virus during 1970, 1971, 1973 and 1974; substantiating that faecal coliforms are not reliable indicators of viral pollution. Other sources of drinking water, i.e. treated dam water (MP20), and borehole waters (MP22 and MP23) all showed evidence of bacteriological and viral pollution during the test period. The microbiological quality of reclaimed water (MP8a) on the other hand was significantly better than the other supplies and at no time could virus be isolated from 10 ℓ or even 100 ℓ of the product water.

Area B

The quality parameters for the various water supplies tested since 1973, are recorded graphically and can be compared with given standards (Figure 3). The waters tested all had chemical qualities within the required health standards. This data may then act as a baseline for the detection of any increase in chemical pollution in the area. These findings may be used to assess the quality of the reclaimed water produced by the experimental municipal wastewater plant in this area (not used for drinking purposes as yet). To date, this reclaimed water complies with all salient chemical requirements and was in fact mostly of better quality than the other drinking water sources, especially with respect to organic carbon content.

The microbiological monitoring of this area (see Figure 4) has occasionally shown evidence of faecal coliforms in the treated dam water (P2) and in the fountain and spring waters (P4, P6 and P7). The major water supply (R4), taken from a polluted river source, meets the required standards probably on account of higher efficiency of the water treatment process. No virus was isolated from any of the drinking waters in this area. No E. coli/100 mℓ or virus/100 ℓ were ever isolated from the final water from the reclamation plant. Again the reclaimed water was of equal if not better quality than the other drinking waters supplied to the area.

Cytotoxicity studies

An investigation of the methods to be used in this study is still to be completed. Cytotoxicity has been detected in the humus tank effluent which constitutes the influent to the reclamation plant in area B but not in the reclaimed water. In-depth studies are still necessary for the interpretation of these cytopathic effects.

Investigations into the spread of R^+ bacteria

Extensive work on the presence and significance of antibiotic resistant bacteria in the water environment has been done (19,22-25). Resistance (R) factors are nucleic acid elements which are rapidly transmissible by conjunction among gram-negative bacteria. They confer on their

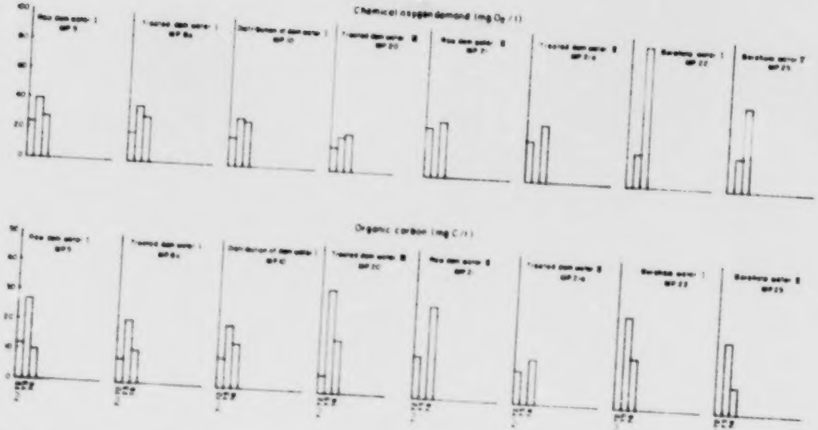

Figure 1. Chemical qualities of raw and treated drinking waters Area A.

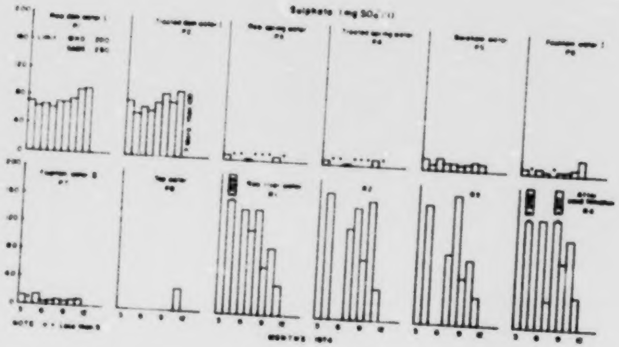

Figure 3. Chemical qualities of raw and treated drinking waters Area B.

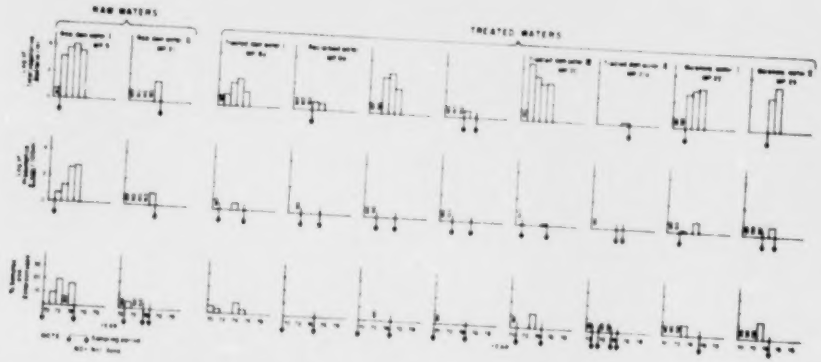

Figure 2. Microbiological qualities of raw and treated drinking waters Area A.

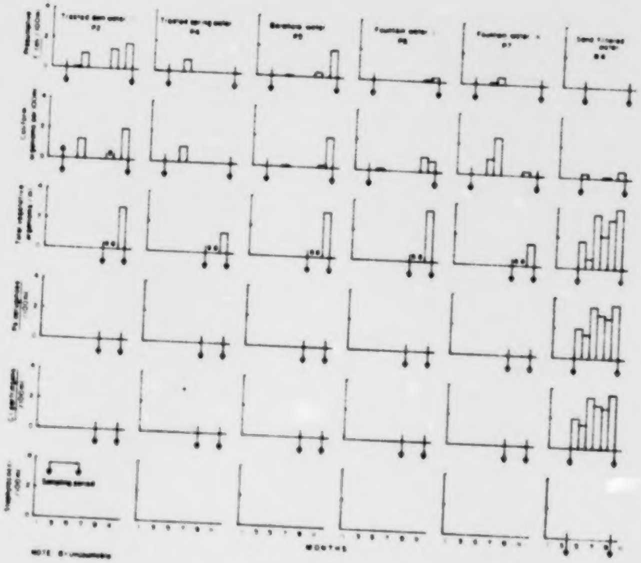

Figure 4. Microbiological qualities of treated drinking waters Area B.

hosts, resistance to antimicrobial drugs and resistance to many other anti-bacterial effects such as those of heavy metals, ultraviolet light, phages, bacteriocins and various chemicals. High numbers of coliform bacteria were found to carry R factors in sewage effluents and in natural waters. In the wastewater discharge of a hospital, about six times as many coliforms carried R factors as did the coliforms isolated from the sewage effluent of the city in which the hospital is located. Coliforms with R factors were found to survive maturation pond treatment and natural purification in a river or a dam as well as, or better than, their components without R factors. R factors may be transmitted among bacteria in the water environment, indicating that polluted water may contribute to the spread of R^+ bacteria, which are a hazard in human and veterinary medicine. More advanced purification of sewage discharges with complete destruction of all bacteria is the only way by which the incidence of these organisms in the water environment can be reduced i.e. the direct reclamation of sewage could solve this problem.

The determination of possible long-term effects by bio-assay

Spent activated carbon from the reclamation plant in area A was treated with chloroform and methanol to extract adsorbed organic material. The recovered material was then tested for carcinogenic activity via the subcutaneous route in rats of a Wistar-derived strain. The skin and subcutis at the site of injection and the liver from each rat were examined histologically. A few pathological changes were observed in the sections examined, but no lesions of significance occurred in these sections. The mean body weights of the eight groups were similar throughout the experimental period. The use of the rat's subcutaneous tissue as a site for testing substances for carcinogenicity is well documented and is considered to give a very sensitive index of carcinogenicity.

As no evidence of carcinogenic activity of the extracts was obtained, testing of extracts on other species by other routes was considered. Instead of adsorbing the organic material onto activated carbon with subsequent recovery of the adsorbed material by chemical means, rats are directly supplied with the water to be tested. In doing so, it is hoped to obtain a more realistic picture of the effects of exposure to water from different sources. The waters tested are: humus tank effluent, reclaimed water from area B, reticulated water from the same area, and distilled water as control. In addition, spent activated carbon is mixed into the diets of rats to examine the effect of oral intake of adsorbed organic material, using new activated carbon as a control. This experiment is being conducted over a long period and no results are available at this stage.

Fish have proved useful sensors of quality changes in water and use is therefor being made of a fish bio-assaying system to continuously monitor reclaimed and other waters for toxicity in area A (26,27). Fish are also used to measure any long-term effects of pollutants. Measurement of growth tempos over 3, 6, 9 and 12 months and other pathological investigations are being carried out on fish housed in aquaria receiving reclaimed water as well as water from other sources. Tests are also being carried out to determine the toxicological effects on fish of known pollutants, some of these results have already been published (28).

Epidemiological survey

Although epidemiological studies have a low priority, information is still accumulated in a study in area A, as described by Grové (29). Data collected should form an acceptable base line of gastro-intestinal infections, central nervous system diseases, hepatitis, and other miscellaneous diseases which may be transmitted by water. To date there does not appear to be any significant change in the disease pattern in the area, but valuable experience in the collection and interpretation of data has been gained.

DISCUSSION AND CONCLUSIONS

This research programme makes provision for studies on eight different research aspects, six of which are already in progress. Only two years of a ten year programme have passed and it is rather early to draw positive conclusions. However, use has also been made of additional background knowledge, gained over the years in the qualities of freshwaters and reclaimed waters, together with data collected during these two years, in an attempt to form a base line on which to measure future deviations in water qualities in the Republic.

The waters under surveillance are representative of the over-all water supplies in the country, the total area investigated includes water supplied to 25 per cent of the total population, and it is with these water supplies that the quality of reclaimed water may be compared. Concurrently, more sensitive techniques for the determination of micro-pollutants are being developed which should assist in the setting of more realistic standards for their limits in drinking waters.

It is not feasible to test the safety of a drinking water prior to its use. Some of the analyses, e.g. viruses, take up to 30 days to complete. Enormous reservoirs would be required if water were to be stored until such results were available. Analytical results can therefore only be used to confirm the quality of a water. Reliance should rather be placed on a knowledge of the source of the water, on the efficiency of the treatment process used and the control of process operations. All these factors are built into the present reclamation processes. In the above study, in all the cases where micro-organisms were found in drinking waters, their presence was the direct result of poor plant operation or design.

Industrial effluents should be treated separately from domestic sewage. This would minimize the effect of the discharge of new and complex chemicals on sewage purification processes and ensure their absence from reclaimed municipal wastewaters.

Epidemiological and bio-assaying studies have not been able to demonstrate any adverse health effects from the use of reclaimed water on humans and rats. The quality of the reclaimed water, tested to date, meets all the quality standards and is equivalent to or better than the best drinking waters obtained even from protected surface water resources.

It is concluded that more research is needed to determine:

1. What pollutants are present in the water environment.
2. The quality of drinking water supplies now and in the future.
3. The influence of industrial wastes on municipal wastewater effluents.
4. Oncogenic effects by means of cell culture studies.
5. The possibility of the spread of R^+ bacteria.
6. The long-term effects of pollutants by bio-assaying techniques.
7. The immunological pattern in the receiving community.
8. The continuing development of analytical techniques for use in the above tasks.
9. The most efficient methods of control of plant operation, design and automation.

ACKNOWLEDGEMENT

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DISCUSSION

COMMENT: Mr. Robert T. Christian, University of Cincinnati, Ohio. I wish to compliment you on the wide range of tests you are using. I was particularly interested in your cell culture type tests. We, too, have studied raw waters and finished waters and direct reuse waters, and I would like very much to compare results with you.

COMMENT: Dr. Lennette, State of California, Biomedical Labs., Department of Health, Berkeley, California. This is not with specific reference to Dr. Nupen's presentation, but in response to everything I have been hearing all day, I would like to make a few comments on viral taxonomy and nomenclature.

About thirty years ago, there was devised the term arboviruses which was a catch-all designation for classifying those viruses transmitted by insects--arthropods. Subsequently, with the era of the tissue culture, we began to isolate viruses in culture and, as you know, there was an era in which we talked about enteric, cytopathic, human organic viruses. This subsequently became what we refer to as enteroviruses.

Also, about the same time, there was recovered a group of viruses now known as the adenoviruses. In their characteristics, except for morphology and the genetic material, they could clearly fall into the enteroviruses because they are found in the gut.

I would remind all concerned that the mere fact that an agent occurs in the gut--in the intestine--is no indication and no proof that it is transmitted by the water route. I give you an example. We were just talking here this afternoon about the hepatitis virus resembling, if I got the message right, the enterovirus group. Now there have been other agents in this group which are now being separated out on the basis of morphology, and the mere fact that an agent falls into this group is no proof that it is water-borne.

In the adenovirus group itself, there are several agents which produce disease that has nothing to do with the respiratory tract. As a matter of fact, adenovirus Type A produces a conjunctivitis, and yet you can find the virus in the gut.

If you get over to the enterovirus group, there is a very outstanding example of a recently discovered entervirus which is responsible for a newly emerging disease known as hemorrhagic conjunctivitis. This agent possesses all the characteristics of an enterovirus, is found in the stools, and yet is not transmitted by that route. So the mere designation of enterovirus should not be assumed to be a label indicating that this agent is, first, necessarily transmitted by water or, secondly, has the gastrointestinal tract as a portal of entry.

QUESTION: Mr. Clive C. Solomons, University of Colorado Medical School. I would like to ask you whether there was any particular problem in eliminating the Filaria parasite during the purification process?

QUESTION: Mrs. Nupen. What was it?

RESPONSE: Voice from the Floor. Schistosomiasis.

QUESTION: Mr. Solomons, University of Colorado Medical Center. O.K. Was that a particularly difficult parasite to get rid of?

RESPONSE: Mrs. Nupen. Actually that's an awfully good question. I haven't been asked that one before. Unfortunately, the National Institute for Water Research (NIWR) does not really deal much with Schistosomiasis, because we have a separate Bilharzia Research Unit which investigates all problems relating to the control of this disease in South Africa. Research has shown that the cercariae in water do not survive longer than 48 hours. They are also killed by low doses of chlorine (1 ppm) and by excess lime treatment. The miracidia, which could presumably be present in municipal wastewater, die after 24 hours if they do not reach a snail host and are killed by 1 ppm free chlorine in contact time 30 minutes. I therefore see no particular problems relating to the transmission of Schistosomiasis by reclaimed wastewater.

The parasites we are interested in at the NIWR are species of Ascaris, Taenia Strongaloides and Hookworm, all of which are common parasitic infections in Southern Africa. All the above species are successfully removed by sedimentation during treatment with excess lime. The ova, however, can be recovered from the resultant lime sludge, and research is necessary to ensure their inactivation prior to the disposal of such solid wastes for agricultural purposes.

PLANNING FOR WATER REUSE: SOME SOCIO-ECONOMIC ASPECTS

J. Gordon Milliken
Industrial Economics Division
Denver Research Institute
University of Denver
Denver, Colorado 80210

Lucy Black Creighton
Department of Economics
Colorado Women's College
Denver, Colorado 80220

ABSTRACT

Economic trends in water resources development, in agriculture, and in energy, together with environmental concerns and regulatory trends affecting wastewater discharge quality, combine to strengthen the case for potable use of recycled water. This paper analyzes the factors which are causing cities to consider reuse of water and indicates some of the socio-economic problems which may occur: (1) possible differences between the public's indicated attitude toward potable use at some future date, and that attitude when directly faced with such use; (2) problems faced by cities pioneering reuse; (3) problems arising from differential application of recycled water among neighborhoods within a municipal system; (4) the need for contingency plans if scheduled implementation of water reuse should be delayed by the discovery of serious health effects; (5) politico-economic conflicts arising between water supply and wastewater treatment agencies, including the problems of equity and efficiency in allocating the costs of reused water treatment; (6) water pricing; (7) in view of rising energy costs, the economic aspects of energy required for wastewater reclamation for reuse; and (8) implications of reuse for downstream water users. Numerous uncertainties exist in these topical areas, and a coordinated research program to provide guidance to policy makers is clearly in the public interest.

INTRODUCTION

The case for renovating and directly recycling wastewater from municipal and industrial sewage is increasingly gaining support in the United States today. In spite of the fact that some people may view with aversion the prospect of having treated wastewater come through their household water taps, technology has made it possible to return wastewater to a quality level which with few, though nevertheless important, exceptions equals that of pure natural sources. While the cost of treatment is still relatively high, there is every expectation that it will decrease over the years as the technical processes are further refined. However, the most significant sources of support for the use of recycled water owe less to the technical ability to purify wastewater than to a number of other considerations having to do with problems of developing new "fresh" water supplies and disposing of municipal and industrial wastewater.

As water use in the United States increases, the costs of developing new conventional water supplies continue to climb, and in many areas of the nation, traditional sources of municipal and industrial water are beginning to be fully appropriated. The problem is particularly severe in arid and semiarid areas, but it is increasingly evident in more humid areas as well. Concurrently, the task of dealing with domestic and industrial wastewater becomes more onerous as population continues to concentrate in urban areas. The volume of such wastes is increasing; it includes ever greater levels of pollutants, and it is difficult to dispose of. Not only is this waste an aesthetic problem, but it has led to the pollution of conventional sources of drinking water, both surface and, in some cases, groundwater. Moreover, providing for new water supplies and for safe effluent disposal have both been made more difficult by recent changes in the public's attitude toward the environment. These changes, largely reflected in EPA regulations, have imposed restrictions on the development of new water supplies and on the unregulated disposal of untreated municipal and industrial wastes. It is not surprising, then, that recycling, which takes wastewater and processes it into usable water supplies, is being proposed as a solution to the problems of both fresh water supplies and used water disposal.

Furthermore, given the requirements for wastewater quality under the current pollution regulations, it may soon be the case that much of the wastewater will have to be of as high, or higher, quality than is much of the current supply of "fresh" water. It has been estimated that on the average effluent already constitutes about three percent of the M&I water supplies of some third of the nation's population, and in some cities reaches 20 percent of supplies.* Thus, recycling water becomes an attractive option both from the point of view of deteriorating fresh water supplies and of increasingly high quality wastewater.

In recent years a great deal of research has been done on various aspects of wastewater renovation--the potential of reused water in industry and agriculture, the technical processes for renovating water from sewer effluent, the costs associated with different degrees of renovation, comparisons of costs of renovated water and of water from more conventional sources--have all received attention. In the socioeconomic area, however, less research has been done. This paper describes certain social, attitudinal, political and economic topics where uncertainty exists, and points the way for a research program which can help to provide answers for the water reuse planning process.

ATTITUDES TOWARD REUSE

The instinctive public attitude toward consumption of water reclaimed from sewage is one of disgust or fear (or in milder forms, suspicion). This is based on a cultural taboo against association with bodily wastes, which predates an awareness of the association between germs and disease. Given a free choice, it is probable that most persons would shun the recycled water in favor of "fresh" water, even if they were assured of equal purity. In spite of a widespread awareness, for example, that astronauts on space flights consume water which is recycled from bodily wastes by advanced engineering processes which eliminate the possibility of contamination, it appears that few persons would voluntarily choose such water for drinking, so long as a fresh water source were available. What will be the significance of this attitude when municipal recycled water becomes a reality? Will the public accept recycled water for potable use, or will the public require some form of dual system, at considerable expense, to segregate recycled water for industrial or other nonpotable use?

Table I shows the results of nine attitude surveys designed to measure public acceptance of drinking reclaimed wastewater. The results of the surveys are varied. They show a spread of willingness, from less than 40 percent to over 8 percent. This spread can be attributed to many factors: questionnaire design; respondent assumptions; awareness of water problems; geography; and so forth. It is worth noting that absence of choice raises the acceptability of recycled water. In the Carley study, drinking reused sewage water ranked lowest of all (37.8 percent approving) when respondents were given a choice of seven water supply alternatives. However, when not faced with a choice, and given the criterion that the recycled water would be equal in quality to present house water, 84.1 percent showed some degree of approval.*

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*Jerome Gavis, Wastewater Reuse, Washington: National Water Commission, 1971, p.3.

*The Carley study results were: "Yes, definitely," 52.8 percent; "Probably so," 23.7 percent; "Not sure, but tend to think so," 7.6 percent.

TABLE I. PERCENTAGES OF RESPONDENTS WILLING TO DRINK RECYCLED WASTEWATER

Survey Date	Survey Location	Author	Percentage Willing
1965	Texas, Kansas, Massachusetts, Illinois	Baumann	61.4%*
1971	Kokomo, Lubbock, San Angelo, Colorado Springs, Santee	Sims and Baumann	48.0%
1971	Nationwide	Ackerman	60.0%
1971	Philadelphia, Camden, Cincinnati, Tucson, Portland, Oregon	Johnson	77.4%
1972	Northern California	Bruvold	45.0%**
1972	Southern California	Bruvold	42.7%**
1972	Denver	Carley	37.8% (84.1%)***
1973	Nationwide	Gallup Poll/AWWA	38.2%
1974	Southern California	R. Stone & Co.	39.1%

*Ranging from 46 percent in Massachusetts to 74 percent in Illinois.

**Bruvold's responses were reported as a percentage opposed to such use, i.e., 55.0 percent opposed in Northern and 57.3 percent opposed in Southern California. The remainder, as shown in the table, are not necessarily willing to drink recycled water, i.e., some may be uncertain.

***In the Carley study, the 84.1 percent were asked if willing, if water quality were the same as present house water. Without this qualification, and confronted with a choice of alternatives, only 37.8 percent approved.

Only scattered evidence exists as to what people will actually do when confronted with using recycled water, but this evidence tends to support the Carley study. In Windhoek, South West Africa, where direct water reuse is practiced, the quality of recycled water is high and public acceptance has been good. In Chanute, Kansas, however, where a poor quality recycled water was used during a 1956-57 water shortage, public reaction was negative and many persons brought water from neighboring towns or bought bottled water.*

The limited experience with reuse and the variation in survey results indicate that much is still to be learned in this area. Some observers rely on faith that intellectual assurances by public health experts and city officials will avert "irrational" public attitudes opposed to recycled water. They suggest a campaign of education and endorsement by experts to mold public opinion. But any such campaign must be grounded in existing attitudes. How many of the favorable responses, for instance, are due to public support of a program seen as environmentally responsible? How many favorable responses are given glibly, with the comforting knowledge that actual experience is remote in time and probability? (One is reminded of the lengthy reservation list of world's fair visitors some years ago, who indicated a desire to be a passenger on the first rocket to the moon.) Will intellectual reason change to emotional distrust when recycled water first flows from the tap?

As a warning, attention should be directed to analogous campaigns in recent years to promote fluoridation of drinking water. Despite repeated assurances by dental experts and others of the scientific community, there was widespread rejection of fluoridation in public referenda,* and highly emotional appeals against "rat poison" and "communist subversion of our water supply." Technical planning for water recycling is a five- to ten-year process; realization of its potential requires public understanding and support.

Problems of Cities Pioneering Reuse

To pursue this question of attitude one step further, what problems will be faced by cities which pioneer potable reuse? Will the public take little or no notice of direct reuse as is the case now with cities using recycled water for park irrigation? Will visitors pay attention only if the water is unusually hard or brackish? Or will knowledge of direct reuse bring significant public reaction, such as occurred in recent months in New Orleans and Duluth as a result of unfavorable publicity about their water supplies? What possibility exists that the first U.S. city to undertake direct potable reuse might suffer economic effects, such as loss of convention business, a drop in tourism, or sales resistance to food or beverage products produced there? Unless research shows that these concerns are minimal, uncertainties of this sort appear likely to remain barriers to recycling.

DIFFERENTIAL APPLICATION OF RECYCLED WATER

One potential problem of considerable significance appears to have received little or no attention. This is the problem of differential geographical application of recycled water within a municipal system. Most cities of substantial size do not have a single source of water and a single reservoir. The common occurrence is a mixture of water supplies from several different sources. Often there also are several water treatment plants and several water storage reservoirs, each serving a particular section of the city. What happens with direct reuse when the city's water recycling plant, located at or near a major sewage treatment plant, comes on line? Efficiency of the distribution system would dictate that the recycled water be pumped to water storage reservoirs in the general vicinity of the sewage treatment plant. And since gravity sewerage systems are normal, these reservoirs would be in the section of the city of lowest elevation, nearest the outlet waterway which drains from the city. The result of all this is that, normally, neighborhoods near the river basin, in the lowest elevation of the city, would be most likely to receive recycled water. Neighborhoods in higher elevations, at the upstream end of the city, would more likely receive water supplies from traditional sources.

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*Baumann, Duane D., and Roger E. Kasperson, "Public Acceptance of Renovated Waste Water: Myth and Reality," Water Resources Research, Vol. 10, No. 4, August 1974, pp. 667-674.

*James F. Johnson pointed out this analogy in Renovated Waste Water, Chicago, Illinois: University of Chicago, 1971.

It is a foregone conclusion among knowledgeable water resource professionals that recycled water will not be added to the normal water supply until it is demonstrably of equal quality. Thus in theory it should not matter if one neighborhood receives water from a recycling plant while another neighborhood receives water originating in a hillside spring. But this difference certainly will cause grave problems of resistance among those consumers who are supplied with recycled water when this fact becomes known. This problem will become even more difficult if those consumers happen to be economically disadvantaged, or an ethnic minority. Yet it is possible and even probable in many cities, that the section of the city nearest the river, and hence the recycling plant, is older and contains more low income and minority residents that the more distant, newer neighborhoods. It is not without reason that the term "house on the hill" is synonymous with affluence.

One topic for socio-economic research, therefore, is an analysis of strategies that can minimize or eliminate this source of resistance. What should be done if there is to be selective distribution of recycled water in a city? Should there be an educational campaign in advance? Should there be some economic benefit to the area receiving recycled water, such as a dual price system, or would this backfire by implying an inferior quality of recycled water? Should there be an attempt to equally distribute recycled water to all areas of town, regardless of distribution expense?

SOCIAL AND ECONOMIC DISRUPTIONS THROUGH DELAY OF REUSE

In spite of uncertainties about public acceptance, it does appear that expectations for recycled water to become a viable alternative to conventional water supplies are rising. This is most notably true of environmental activists, who view recycling as ecologically sound while conventional water supply techniques, e.g., diversion from streams, construction of storage reservoirs, are viewed as environmentally damaging. Yet questions about the health effects of recycled water are far from settled. The problem to be dealt with here is what to do should implementation of recycled water schemes be suddenly halted by new evidence of recycled water danger.

This environmental pressure is very real and very powerful. William R. Seeger, former General Manager of a California water district describes this phenomenon:

> "The Marin Municipal Water District in Marin County, California, over the past several years had two bond issues defeated that were designed to provide a supplemental water supply for the community. I can say unequivocally that one of the major objections that was brought up which was effective in defeating our bond issues was the accusation that we had not adequately taken into consideration the possibility of the reclamation and reuse of wastewater. Our first issue was defeated on a 9-1 vote, which is probably the largest defeat of any major water bond issue in the country. . . . Frankly, I believe that in any program for supplemental water supply, the success of any bond issue is questionable if the possibility of reuse of wastewater is not considered and prepared as a viable alternative. It was suggested to us that if we would include, as part of the bond proposal, money for the construction of a wastewater project regardless of the economics, we could then anticipate a favorable vote and support from those who previously led the opposition."*

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*William R. Seeger, "A Water Manager's Perspective in Water Reuse," presented at

Another example of environmental support for recycling can be found currently in the Denver Metropolitan Area, where environmental groups are opposing construction of a storage reservoir on the Upper South Platte River. In draft statements prepared for the Bureau of Reclamation's Feasibility Report on the so-called "Two Forks" project, recycling was recommended as an alternative by representatives of three environmental groups opposing construction of the dam and reservoir for the Denver water supply system.

There can be little objection to active consideration of water recycling as an alternative strategy for water supply, and many cities are proceeding on the assumption that recycling for potable use will become feasible in another 15 years or so. The problem which could arise, however, is that public health hazards may not, after all, be overcome when scheduled. What happens in 1990 or 1995 if this occurs? What social and economic disruptions follow? If a city has abandoned development of conventional supply sources in anticipation of successful reuse, it cannot reverse strategy and develop these sources in less than a decade or so. Instead, the city would probably face forced conservation of potable use, and expensive dual systems which provide recycled water for various nonpotable uses. The research which appears to be indicated is an assessment of the social and economic impacts on an area, in case potable reuse is indefinitely delayed and the implementation of contingency plans becomes necessary.

CONFLICTS BETWEEN WATER SUPPLY AND WASTEWATER TREATMENT AGENCIES

Traditionally in the United States water supply systems have been separate from wastewater treatment systems. In many areas there are different administrative organizations for each with separate costing and billing. Certainly in the minds of most consumers the two systems are separate and distinct. Planning for water recycling, however, points up the artificiality of this separation and problems of both efficiency and equity which must be considered.

An objective look at a municipal water supply and wastewater treatment system rather clearly demonstrates the technical and economic relationship of the systems. When water recycling evolves from advanced wastewater treatment, the interdependence of the systems becomes even clearer. In particular, the cost of renovated water is closely linked to the level of wastewater treatment. The higher the quality and therefore the cost of wastewater effluent the lower will be the additional costs necessary to produce recyclable water. The product of one system becomes the input of the other, and the volume of one causes a direct impact on the volume, and thus the facility cost of the other. In this symbiotic relationship, economic theory states that maximum efficiency of the total supply/treatment system would occur if both were under a single ownership and operation. But aside from the institutional balance of power between the two agencies and any savings that may come about from closer coordination between them, the separation of charges between water and wastewater is more a matter of equity than of efficiency.

This becomes clearer if specific cases are examined. If municipal water supplies are inexpensively priced, or at a flat rate, consumption rises and a heavier wastewater load enters the sewage treatment plant. This directly causes increased costs of sewage treatment, both capital and operating costs. If sewerage charges are billed to customers based on their winter water consumption (as often happens), this will tend to promote equity. However, if sewerage charges are flat rate, low-use customers help subsidize high-use customers. When the use of one service (sewer or water) is not charged on the basis of volume of use, a distortion in allocation of the service may occur.

When a program of water recycling is implemented, some determination must be made as to the allocation of costs for advanced wastewater treatment between the sewage plant and the water supply agency. What are the transfer costs? Should

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the 94th Annual Conference, American Water Works Association, Boston, Massachusetts, June 19, 1974.

secondary treatment cost be allocated to the sewage plant, and charged against sewage treatment customers, while tertiary treatment costs are charged to the water supply agency and water users? How can these costs be allocated equitably (assuming the absence of a free market) between agencies, whether the agencies are separately owned and operated or departments of the same municipal government? What happens if the water and wastewater agencies do not serve identical populations? Should it matter in cost allocation if the higher treatment is required by pollution regulations on the wastewater as opposed to the water supply agency? Economic research may help provide a formula for cost allocation that will efficiently control the total system and avoid stimulating suboptimization by one part of the system.

WATER PRICING

The question of water pricing is normally based on criteria such as the following:*

a) To recover the costs of operation;

b) To provide an acceptable return on investment;

c) To maintain some type of equity among classes of consumers;

d) To encourage or discourage certain uses of water by certain customer categories, thus influencing levels and patterns of demand.

Most water price structures are based on the assumption that water is of uniform quality. (Although some supply agencies sell both raw and treated water, at different prices, the differential usually is close to the cost of treatment.) Even when water comes from different sources having widely different costs, supply agencies normally use average cost pricing and deliver water to users of the same class (e.g., all in-city metered customers) at the same price (or at the same rate structure, although prices per thousand gallons often vary as a function of quantity used).

With water recycling, new problems arise--particularly during the transition period during which recycled water is produced but not yet distributed for potable use. For example, the City of Colorado Springs, Colorado, operates a conventional potable water supply system and also operates a tertiary treatment facility generating two grades of nonpotable water: an irrigation grade, sold for watering lawns and golf courses; and a high-grade industrial water suitable for use by power plants and other industrial customers. There exists a dual price structure. The potable water is sold at a declining rate, ranging from 90 cents per 100 cubic feet to 45 cents per 100 cubic feet for amounts exceeding 50,000 cubic feet per month. Presumably this price structure for potable water is necessary to cover fixed and operating costs of the conventional water collection, treatment and distribution system. The nonpotable recycled water, of either quality, sells for 22.5 cents per 100 cubic feet. This lower price nevertheless covers the costs of tertiary treatment and distribution through separate pipelines to the customers using nonpotable water for irrigation and industrial purposes.

A city faced with a water shortage benefits from a situation such as that described. That is, the potable supply is saved for new residential users while the nonpotable supply is used increasingly to supply industrial and irrigation demand. However, if the city does not face a current water shortage but is developing recycling to meet a potential need in the future (as is the case with Colorado Springs) the city could find itself in destructive self-competition by providing a cheaper substitute which reduces industrial and irrigation demand for its potable water.

The problem is an economic one, relating to the four pricing criteria listed above. How does a city establish price structures for its two or three grades of water, to assure an equitable price for each class of consumer, to assure efficient use of each grade, and still cover all costs? The chosen structure must serve, without sudden and unpopular price increases to certain customer classes, during the period in which reuse systems are being developed and the relative quantities of each grade of water produced are shifting. Some economic research in price policy is needed to guide the efficient pricing of two or three grades of water, any of which could be used by many industrial or irrigation customers. Ultimately, when the recycled water becomes of potable quality, how are price structures readjusted to maintain equity to all customers, including those who have provided a market for the recycled water during its nonpotable period?

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*Hittman Associates, Inc., Price, Demand, Cost, and Revenue in Urban Water Utilities, Columbia, Maryland, 1970, p. I-1.

ECONOMIC ASPECTS OF ENERGY FOR RECYCLING

Although advanced wastewater treatment and recycling technology varies (e.g., ion exchange, chemical precipitation such as lime coagulation, ultrafiltration, activated carbon filtration, reverse osmosis, ozonation, chlorination) most processes are energy intensive. That is a significant amount of energy is used for pumping through a series of tanks and filters, for filter cleaning, for heating, for calcining or recovering coagulation and filter media, etc. Still more energy is used for the manufacture of chlorine and other necessary chemicals, and ozone.

A very preliminary indication of energy consumption in a tertiary recycling plant can be gained from operating cost data for the two million gallons per day Colorado Springs industrial water plant. An operating cost breakdown for 1974 showed the following (capital charges excluded):

Category	Percentage of Operating Cost
Labor	37.5%
Energy	7.2
Chemicals	40.7
Maintenance	14.6
	100.0%

If the energy used were all electrical, it would represent about 1.70 kilowatt-hours per thousand gallons of recycled water. At the Colorado Springs commercial rate structure, this would cost about 3.1 to 4.1 cents per thousand gallons.

Other tentative energy cost calculations can be found in SCS Engineers' 1973 report* which relates "utilities" costs of operation to production of tertiary treated effluent used in recreational lakes:

	Utilities Costs, cents per 1,000 gallons
Lancaster W.R.P.	0.86 (includes secondary treatment cost)
Santee Co. W.D.	3.58

With the rapidly increasing cost of energy and a growing recognition of its limited supply, there is need for new economic analysis of wastewater treatment facilities and processes. Such analysis would cover the energy used in the total recycling system, including facility construction, operation, and maintenance;** treatment processes; chemical and ozone manufacture; and pumping. By forecasting increases in the cost of various forms of energy, the analyst can influence selection of water recycling technology that is energy effective or cost effective or both.

Any energy analysis of reuse technology should of course include a comparison with energy used in alternative ways of obtaining new water supplies. As Henry Graeser points out:

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*SCS Engineers, Demonstrated Technology and Research Needs for Reuse of Municipal Wastewater, Long Beach, California, 1973, p. 105.

**For example, see Robert L. Pillsbury, "Energy Conservation Through the Architectural Design of Wastewater Treatment Facilities," presented at the 47th Annual Conference, Water Pollution Control Federation, Denver, Colorado, October 9, 1974.

> In the Texas area, pipelines are being built a hundred or more miles in length. Compared to land costs, pipeline costs and energy for trans-basin diversion, advanced waste treatment with planned recycling is quite cost effective.*

IMPLICATIONS OF REUSE FOR DOWNSTREAM WATER USERS

Except for disposition of sludge and other waste matter extracted in advanced wastewater treatment processes, recycling eliminates the problem of sewage disposal. In most regions of the country this will be a real benefit; underground water supplies and surface supplies as well will no longer be contaminated by municipal and industrial wastes. But it should be pointed out that, in areas of the country where water is in short supply the situation may be quite different. In these areas, a large city may use a major portion of a river's flow for municipal water supply, so that consumptive use significantly diminishes the quantity of downstream flow. If, as the city grows, it relies on water recycling to provide additional water supplies, consumptive use rises as a proportion of natural river flow. Thus, downstream users will be cut off from some portion of their accustomed water supply, even though it might have been water of inferior quality. Obviously, this can cause grave economic and social problems. What the consequences of this are will depend upon the legal and institutional considerations of each particular case. Some research into downstream effects may help establish a basis for equitable adjudication of disputes as well as a basis for sound water resource planning.

CONCLUSION

As this discussion has suggested, it would appear that the principal question with regard to recycled water is not so much whether or not it will become a part of municipal water systems, but whether or not it can be efficiently and equitably integrated into the economic and social framework of existing systems. Without attention to the problems discussed here there is a possibility that the technical capability for renovating wastewater will outrun the capacity of the social and institutional framework of which it must be a part. Thus for the time being, where recycled water can be made available at a cost competitive with other water, every effort should be made to begin to substitute it for conventional water at levels farthest below human contact. This will lengthen the life of present water supplies and provide the time for a coordinated research program to develop guidance in the socio-economic areas outlined above. This guidance for water resources policy makers is clearly needed and is in the public interest.

DISCUSSION

COMMENT: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. You raised one question concerning what costs are allocated to waste treatment and what costs should go to the user. Most waste treatment plants are now under NPDES permits for discharge to the waters of the nation. And we, at least, have tended to follow the rule that the waste treatment facility is responsible for all costs associated with meeting those NPDES limits for discharge, and that a water user who wants additional treatment would then pay for the additional treatment or the distribution system, and things like that, but that there is a national break-point established by our existing EPA-NPDES limit program.

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*Henry J. Graeser, "Water Reuse--Resource of the Future," presented at the 94th Annual Conference, American Water Works Association, Boston, Massachusetts, June 19, 1974.

Charge to the Workshop

Albert C. Trakowski
Director, Office of Environmental Engineering
Environmental Protection Agency

Thank you for taking time out from your busy schedules to come to the University of Colorado and participate in this Workshop. This is the third in a series of Research Needs Workshops sponsored by the Environmental Protection Agency. The first Workshop was held at the University of Illionois, Champaign - Urbana, in July 1973, to develop research needs for Recycling Municipal Sludges and Effluents on Land. A second Workshop on the Automation of Wastewater Treatment Systems was held at Clemson University, South Carolina in September 1974. This Workshop is co-sponsored by EPA, the Water Pollution Control Federation and the American Water Works Association in cooperation with the University of Colorado. Again I would like to emphasis that this Workshop is to define and establish priorities for research needed to develop confidence in the reuse of municipal wastewater for potable purposes. Although we realize that the reuse of municipal wastewaters for various other non-potable uses will probably in most-instances be utilized first, we are of the opinion that non-potable reuse goals can be achieved effectively and safely with today's water pollution control technology and therefore, do not require a major research effort. On the other hand, reuse for potable purposes requires a long-range research program in which we must embark on now in order to effectively cope with the critical water supply problems projected to face this nation.

In the past, the Office of Research and Development used several mechanisms to obtain research needs from the user community. However, because of a variety of reasons, the research needs solicited by these methods were often inadequate and could not be molded into an effective research program.

Therefore, we have initiated Workshops in order to invite the most knowledgeable people in the United States, and in the case of this Workshop, probably the World, to analyze a particular research area and develop specific research needs in order to attain a specific goal. To repeat, our specific goal during this Workshop is to define research needs in order to develop confidence in municipal wastewater reuse for potable purposes.

Before arriving at this Workshop, a packet of information was sent to each of the invitees. In this packet, there is a preliminary draft of a municipal wastewater reuse strategy to which Mr. Frank Middleton alluded to earlier in today's program. This strategy outlines a reuse program on which EPA is planning to embark on and is ready to make a long-term commitment. Again I would like to emphasis that this is a preliminary document,not an official EPA policy, nor endorsed by the various organizations within EPA. It is, however, a start at defining an Agency goal. Your comments and suggestions on this document will be most appreciative.

Your charge during this Workshop will be to develop specific research needs in your area of expertise so that EPA can accomplish the goal of potable reuse confidence. The specific research needs and tasks that you develop, will be coordinated and used as building blocks to meet this goal.

Each of you has been assigned to a Workshop group session. We have made assignments so that each workgroup will have a manageable number of participants so that there can be a good interplay of information. If for some reason you have not received a Workgroup assignment, please see John English from EPA and he will assign you to a Work group.

There are six Workgroups:

1. Wastewater Treatment for Potable Reuse (Technology)
2. Treatment Reliability and Effluent Quality Control for Potable Reuse
3. Health Effects of Potable Reuse Associated with Inorganic Pollutants
4. Health Effects of Potable Reuse Associated with Organic Pollutants
5. Health Effects of Potable Reuse Associated with Viruses and Other Biological Pollutants
6. Socio-Economic Aspects of Potable Reuse

We have selected as Work group chairmen, experts outside EPA in the respective fields. Their job is to stimulate discussion, assimulate the research needs developed, and report the Work group findings back to the entire Workshop participants. To assist in the Work group discussions, we have selected from within EPA, experts in their respective scientific fields to serve as Co-Chairmen. To open discussions our Co-Chaimen have developed a list of questions which in their opinion require guidance, direction and possible further research. We hope that these questions can help guide each Work group as they develop research needs.

Remember the purpose of this Workshop is for EPA to learn from you. In your work group, we expect lively debate, perhaps polorization of discussion, since many of you where selected to participate in this Workshop because you represent various schools-of-thought. Please express your thoughts, so that the best possible research needs can be developed.

From your Work group session we would **like specific research needs developed** (A sample Research Need and instructions are attached). If possible we would like a brief discussion with each research need developed as to the reasoning for it. Additional information as to suggested approach and suggested length of study would be appreciated. Please do not get side tracked as to specific language, wording, or format, as it is your thoughts that count. After you develop your research needs, please try to prioritize the needs as you see fit. I suggest you try three general categories (high, meduim and low).

Tonight, after you have dinner please report to your respective Work group assignments. This evening the Work group can use the time to get acquainted and start to formalize research needs. We will try to follow the schedule as closely as possible. On Thursday morning, the Work group Chairmen will report back to the entire Workshop the findings of their group. At that time everyone will be able to comment on the other sesssions and we will try to incorporate the individual comments into the final findings of the Workshop.

We expect that the following two days will be shirt sleeves sessions, perhaps containing controversy on many issues, but hopefully what will result will be the foundation and the development of building blocks for a successful research program aimed at obtaining confidence in the reuse of municipal wastewater for potable purposes.

Guidelines for Developing Research Needs

If possible, specific research needs that are developed should contain the following information:

1. Statement of Specific Research Need (can be one sentence)
2. Discussion
    - Reason for Specific Research Need
    - Suggested approach to the problem
    - Suggested length of study
3. Priority
    - High
    - Medium
    - Low

Sample Research Need

I. Development and demonstration of treatment processes are needed to ensure the removal of heavy metals to levels suitable for potable reuse.

Discussion

Heavy metals are entering the municipal waste stream in even increasing quantities. Research is needed to show that these compounds can be effectively removed. The major heavy metals that should be addressed first are Ag, Cd, Cr, Cu, Fe, Mu, Ni, Pb, Zn, Ba, Se, Hg, Co, Mo, As, and B. Sampling should be done on a 24-hour composite basis every other day. A one year study fulfills this requirement. We feel that physical-chemical processes should be explored first, since it is our opinion that these processes can ensure a greater treatment reliability than the biological unit processes.

WORKSHOP SESSION SUMMARIES

The objective of the Research Needs Workshop was to define and establish priorities for research needed to develop confidence in the reuse of wastewater for potable purposes. The following six Workshop Sessions were designed to achieve this objective:

1. Treatment Reliability and Effluent Quality Control for Potable Reuse.
2. Wastewater Treatment for Potable Reuse.
3. Health Effects of Potable Reuse Associated with Inorganic Pollutants.
4. Health Effects of Potable Reuse Associated with Viruses and Other Biological Pollutants.
5. Health Effects of Potable Reuse Associated with Organic Pollutants.
6. Socio-economic Aspects of Potable Reuse.

The participants of each workshop group were selected to represent a broad spectrum of technical expertise as well as a variety of organizational backgrounds. Summaries of each of the six Workshop Sessions, including a list of participants, follow.

WORKSHOP ON TREATMENT RELIABILITY AND EFFLUENT QUALITY CONTROL FOR POTABLE REUSE

Chairman: Michael A. Bellanca, Virginia State Water Control Board
Vice-Chairman: John M. Smith, Environmental Protection Agency, NERC
Cincinnati, Ohio

1. INTRODUCTION

The research needs which will be presented by the Task Force on "Treatment Reliability and Effluent Quality Control for Potable Reuse" will be presented below in four parts:

- Reliability Goals
- Factors Affecting Plant Reliability and Effluent Variability
- Design Considerations, and
- Operational Controls

Research needs which are addressed herein have been placed in one of the four above categories. It is apparent that there are grey areas and some needs can fit in one or more categories. These categories were developed to provide a step by step process which might lend itself to development of suitable research timetables. The questions which had been formulated for discussion by the Task Force were treated as starting points and were not adhered to rigidly. The research needs presented are the result of a group concensus and opportunity was allowed for minority statements. In view of the time allowed for development of these needs, it was not possible to develop:

- Approach to the Research;
- Length of Study; and,
- Projected Costs of the Proposed Research.

The participants feel that technology transfer is essential and that information should be made available to designers, systems managers, operators, etc. as soon as it becomes available. This may well fit within the current program of EPA.

Several participants requested that the record show that participation in the Workshop should not be taken as representing tacit approval of direct potable reuse. It was the concensus that we were investigating possible reuse in the future and that we would be seeking to develop a long-term research plan in the event reuse becomes a reality. It was the further concensus of the participants that the present drinking water quality standards were completely inadequate for potable reuse.

2. IDENTIFIED RESEARCH NEEDS

A. Research Needed to Define Reliability Design Goals

1. Fail-Safe Reliability (High Priority)

   Need - To define fail-safe reliability and determine those factors or procedures which will assure fail-safe operation essential to the production of a safe potable water from domestic wastewater.

   Reason - Protection of public health dictates that water produced from reuse systems is continually assured that water of a questionable quality can never enter the distribution system.

2. Water Quality Standards for Potable Water Reuse (High Priority)

   Need - Develop water quality standards specifically for potable water reuse.

Reason - The currently applicable drinking water standards were derived for raw water sources of a different character. Water sources contemplated for potable reuse systems contain a greater variety of constituents which are often present in concentrations much higher than found in conventional raw sources.

3. Determination of the Limits of Variability Allowable for Specific Water Quality Parameters (Medium Priority)

    Need - To determine the allowable variability and thus the allowable sampling or continuous monitoring frequency required to insure adequate process control and removal of specific contaminants in a reuse system.

    Reason - Before successful reliability design can be achieved, it is necessary to explicitly define the contaminant removal goals in terms of allowable effluent concentration and the acceptable time varying ranges in concentrations suitable for domestic consumption. Distinction must be made for contaminants that may result in chronic and acute health effects.

4. Interdisciplinary Project Formulation (Medium Priority)

    Need - Research is needed to develop the form and financial aspects of a reuse needs study. Guidelines should be developed for the use of state and community authorities to prepare minimum but comprehensive scopes of work for feasible and engineering studies of treatment alternatives as a sound basis for minimal budgeting.

    Reason - When a move starts in a community for additional wastewater treatment the custom is to have one or more of the political leaders ask a friendly engineer or community public works head for a rough budget to accomplish the wastewater treatment needs. At this point it is very important that the needs be reviewed by a group of interdisciplinary experts, i.e., socio-economic, ecological-environmental, environmental engineer, planner, political scientist, etc. This group, selected jointly by community and state authorities, should develop the scope of work needed to conduct a feasibility study and develop a budget for further engineering and planning studies.

B. Factors Affecting Plant Reliability and Effluent Variability

1. Variability of Influent Constituents (High Priority)

    Need - To define the variability of specific influent wastewater constituents as it affects reliability of unit process or overall system removals.

    Reason - The overall performance of a reuse treatment system will be affected by the time dependent changes in the mass flow (concentrations x flow) of some influent wastewater constituents, and by shock loading of toxic or treatment inhibiting substances when biological processes are employed. The changes in influent characteristics must be known to permit knowledgeable selection of unit processes and to predict unit processes or system effluent variability.

2. Evaluation of Current Treatment Technology (High Priority)

   Need - Research is needed to determine the contaminants present in domestic water supplies today and to evaluate the treatment processes currently in use to determine if these contaminants can be controlled, and at what levels.

   Reason - Contaminants of concern are present in many domestic raw water sources today as a result of upstream municipal and industrial waste discharges. If the current treatment technology is evaluated as regards the removal of these contaminants, it will be possible to speed development of potential reuse schemes and process trains.

3. Reliability of Domestic Waste Systems and Domestic/Industrial Waste Systems (High Priority)

   Need - There is a need to determine the reliability of systems which treat only domestic waste and those which treat combinations of domestic and industrial waste.

   Reason - There are a variety of contaminants which can find their way into waste treatment systems. It is felt that domestic sewage may provide a medium much more amenable to potable reuse and reliability, and that it may be more easily characterized in terms of its constituents. Many systems treat industrial as well as domestic wastes and often the industrial constituents are either unknown or can be rapidly changed as a result of in-plant changes and product mix, thereby creating a potential for stress of a potable reuse system.

4. Effect of Recycle Stream, Added Chemicals or Chemical Reaction By-Products on Process Variability and Reliability (High Priority)

   Need - To assess the impact of recycle side-streams, extraneous chemical additions, and chemical reaction by-products on variability of unit process and total system performance.

   Reason - The specific end products resulting from each process used to treat domestic wastewater for reuse as a potable water may change the form of the original contaminant or add new constituents that are unacceptable. Chlorination, dechlorination, ozonation, heat treatment, among others, can under certain circumstances produce additional unsafe constituents that must, in turn, be removed to insure a safe potable water.

5. Risk Analysis of Acute and Chronic Effects (High Priority)

   Need - Research into the acute and chronic effects of effluent constituents and the development of a "Risk Analysis" procedure which can be used to determine the consequences of exposure on the basis of concentration and time, and the associated cost to remove these contaminants to the desired level with the desired degree of reliability.

   Reason - Some contaminants in domestic wastewater are now or will be identified as having an acute or chronic effect when present in varying concentration in reused wastewater. The cost of removing these contaminants in reuse systems will vary depending on the variability and reliability of removal required. Effective design and operation of reuse systems dictates that removal goals and permissible variation in removal efficiency be established.

6. Development of Technology Assessment Program (High Priority)

Need - To develop a program which will:

(a) Evaluate new products as they become available in the market-place.
(b) Determine their impact on potable reuse systems; and
(c) Disseminate the information to the water industry along with an evaluation of suitable treatment alternatives.

Reason - The rapid expansion of technology will bring new pollutants into the domestic and/or industrial waste stream. Reuse systems designed at a certain point in time may become rapidly outdated as these pollutants enter the system and are not amenable to the treatment schemes in use.

C. Design Considerations

1. Reliability of Various Reuse Schemes (High Priority)

Need - Once given the various reuse schemes research will be necessary to determine the reliability of each and the potential to continuously achieve the water quality standards applicable to potable water reuse.

Reason - Any number of process trains may be proposed for processing water destined for potable reuse. The reliability of each system and its capability to produce water of an acceptable quality on a continued basis will be the criteria by which particular systems may be chosen.

2. Variability of Influent Constituents (High Priority)

Need - To define the variability of specific influent wastewater constituents as it affects reliability of unit process or overall system removals.

Reason - The overall performance of a reuse treatment system will be affected by the time dependent changes in mass flow (concentration x flow) of some influent wastewater constituents, and by shock loading of toxic or treatment inhibiting substances when biological processes are employed. The changes in influent characteristics must be known to permit knowledgeable selection of unit processes and to predict unit processes or system effluent variability.

3. Equipment Development (High Priority)

Need - Once specific reuse systems are chosen they should be researched to determine if there is a need for types of equipment not available at the time; the needed reliability of such equipment should be determined and design specifications developed.

Reason - Available equipment might not be suitable for use in a proposed reuse scheme. Equipment will have to be developed for a specific reliability in mind. Once developed, specifications will follow and should be made available to design engineers and systems managers.

4. Investigation of Equipment Failure Frequency and Impact of Failure on Unit Process and Total System Performance (High Priority)

Need - Research is needed to investigate the frequency of failure of key pieces of equipment in various unit processes as a function of service life. Also needed is an evaluation of the impact of equipment failure on unit process and overall system performance. The study should include cost effectiveness studies of alternate back-up systems and should outline the development of contingency plans for overcoming system failure.

Reason - One of the principle sources of unreliable process performance is equipment malfunction. A firm knowledge and understanding of the causes of failure and expected lifetime of key process equipment will permit the design of a more reliable system.

5. Minimum Plant Size (Medium Priority)

Need - Research is needed to determine the minimum size plant amenable to reliable operation for the production of potable water for reuse.

Reason - One of the prime reasons for poor plant reliability is the plant operator. It is felt that the poorest operation is generally found, for a variety of reasons, in plants of small size and that larger utilities stand a better chance of attracting the type of qualified personnel necessary for reliable production of potable water for reuse.

6. Development of Indicator Parameters for Continuous Monitoring (High Priority)

Need - Research should be undertaken to develop suitable organic and biological indicators which could be automated and be used to monitor effluents from potable reuse systems. The resulting input would be used in an appropriate automatic feed-back control system and would also be used as decision logic to divert sub-standard effluent to holding basins for further treatment or discharge to a receiving stream.

Reason - The key to effluent quality control in reuse systems lies in the availability of suitable monitoring systems to describe process water quality of the influent and effluent streams as well as the inter-process streams. Because of the larger number of specific contaminants to be monitored in the process effluent stream and the projected high cost of analysis, it is imperative that a few specific indicator parameters be identified that can be correlated with the more specific contaminants that are of greatest concern from an acute and chronic health effects standpoint. The indicator parameters should be developed to replace such gross tests as BOD_5, CCE, etc.

D. Operational Controls

1. Essential Operation and Control Strategies (High Priority)

Need - Research is needed to determine essential operation and control strategies.

Reason - Potable reuse systems are likely to be very complex. In order to assure consistent fail-safe removal of all pathogens and toxic substances it will be necessary to have operational and control procedures which will give step by step instructions for the operation of the various reuse schemes and contingency for appropriate actions in the event of specific unit process failures.

2. Management and Organizational Requirements (Medium Priority)

Need - Research is needed to determine the types of management organizations which can effectively and reliably assure operation of all processes required to consistently remove all constituents in wastewater that would otherwise render it unsuitable for potable reuse.

Reason - In order to assure continuous reliable operation of selected reuse systems, it will be necessary to assure the availability of adequately trained and motivated personnel and to provide all necessary back-up services (e.g., spare parts, electricians). These requirements may vary with the size of the facility, the community served, and its location in the United States.

3. Operator Capability and Compensation Requirements (Medium Priority)

Need - Research should be undertaken to define the complete staffing requirements of reuse systems. The study should include job descriptions, required training, and capabilities of all job categories needed for the efficient and successful operation of reuse systems. Emphasis should be placed on special staffing needs, such as electricians, maintenance, etc., that may be required because of the higher level of process control required.

Reason - Because of the high degree of reliability required and the complexity of reuse systems, successful operation will require a much higher level of operation and maintenance than normally provided for conventional wastewater or water treatment plants. In some cases the special technology employed will require special skills in the areas of operation, maintenance and analysis. Consideration must be given to the higher salary requirements that are needed to attract and maintain adequately trained personnel.

4. Develop Indicator Parameter Amenable to Continuous Monitoring (High Priority)

Need - Research should be undertaken to develop suitable organic and biological indicators which could be automated and be used to monitor effluent from potable reuse systems. The resulting input would be used in appropriate automatic feed-back control systems and would also be used as decision logic to direct sub-standard effluent to holding basins for further treatment or discharge to a receiving stream.

Reason - The key to effluent quality control in reuse systems lies in the availability of suitable monitoring systems to describe process water quality of the influent and effluent streams as well as the inter-process streams. Because of the large number of specific contaminants to be monitored in the process effluent streams and the projected high cost of analysis, it is imperative that a few specific indicator parameters be identified that can be correlated with the more specific contaminants that are of greatest concern from an acute and chronic health effects standpoint. The indicator parameters should be developed to replace such gross tests as BOD_5, CCE, etc.

5. Preventive Maintenance - Instrumentation (High Priority)

Need - Research is needed to develop and demonstrate preventive maintenance programs for automatic process control and monitoring systems. Research should also include back-up systems for fail-safe operation. Prime and back-up systems will be interfaced to provide automatic cross-checking.

Reason - Treatment reliability and fail-safe operation will depend on the accuracy of the automated instrumentation and the operability of the control and fail-safe systems. Preventive maintenance of these systems will insure their continued accuracy and availability to perform the functions for which they are designed.

6. Research to Determine Optimum Sampling Frequency (High Priority)

Need - A study is needed to determine the number and frequency of effluent samples required for various wastewater constituents to insure adequate process control and effluent product quality. Examination should be given to the frequency required for contaminants identified as causing both chronic and acute health effects.

Reason - Some parameters of reused wastewater quality will require more frequent monitoring than others. Some must be monitored continuously, while others may be monitored less frequently depending on the potential health risk or toxicity effects. Cost effective operational control requires optimization of sampling and analysis to minimize analytical costs while assuring that quality goals are met.

7. Development and Demonstration of Preventive Maintenance Programs for Process Equipment (High Priority)

Need - Development and demonstration of preventive maintenance programs are needed to extend the lifetime and increase the reliability of major or key equipment employed in reuse systems. The preventive maintenance program should include the development and preparation of operation manuals, needed spare parts, inventories, and the identification of inspection procedures and techniques to reduce down-time due to maintenance related equipment failure.

Reason - Successful implementation of effective preventive maintenance techniques and procedures can potentially reduce maintenance related down time of critical process equipment, thereby increasing system reliability.

Workshop Participants:

Michael A. Bellanca - Chairman, Virginia Water Control Board, Richmond, Virginia.

Paul D. Haney, Black & Veatch, Kansas City, Missouri.

R. E. Leffle, Camp, Dresser & McKee, Inc., Boston, Massachusetts.

William Long, EPA, Washington, D.C.

Henry J. Ongerth, California Department of Health, Berkeley, California.

Joseph Roesler, EPA-NERC, Cincinnati, Ohio.

John M. Smith - Vice Chairman, EPA-NERC, Advanced Waste Treatment Laboratory, Cincinnati, Ohio.

Sheldon O. Smith, Environmental Conservation Programs, Mineola, New York.

Michael J. Taras, American Water Works Association, Research Foundation, Denver, Colorado.

Vern W. Tenney, EPA, San Francisco, California.

Stephen W. Work, Denver Water Department, Denver, Colorado.

Robert L. Wortman, Oklahoma State Department of Health, Oklahoma City, Oklahoma.

Darwin Wright, EPA, Washington, D.C.

DISCUSSION

QUESTION: Moderator Convery, AWTRL, U.S. EPA, Cincinnati, Ohio. I've got one question. Did your committee address the difference in reliability requirements for acute versus chronic materials? This came up in our workshop and we certainly were very interested in preventing the periodic discharge of acute toxicants. However, we felt that a less stringent standard might possibly apply for chronic toxicity. Was this addressed at all in your workshop?

RESPONSE: Mr. Bellanca, Virginia Water Control Board, Richmond, Virginia. It was only addressed in the sense that we were speaking of the need for monitoring and that, for example, the requirements for acute monitoring would be much more stringent than those for the chronic, as you mentioned. We did not take into consideration the fact of the discharge into the receiving streams, but we did take into account proof of acute and chronic health effects just in terms of the reliability because we realize that they will affect the reliability to certain degrees. That was one of the research needs that we identified, but not in the sense of a discharge to receiving waters. That was your question.

COMMENT: Moderator Convery, AWTRL, U.S. EPA, Cincinnati, Ohio. I am referring to the standard of performance associated with contaminants considered to have acute toxicity versus those which are said to have chronic toxicity.

RESPONSE: Mr. Bellanca, Virginia Water Control Board, Richmond, Virginia. This is one of the needs which we identified as requiring some research. That is implicit in one of the recommendations that we made.

COMMENT: Mr. Roesler, EPA-NERC, Cincinnati, Ohio. I would like to say, in regard to these acute and chronic materials, we decided there should be some work in determining the optimum monitoring frequency for certain types of pollutants. In a sense, this would keep us up to date on what is coming out of the plant. For certain pollutants, of course, we felt that because of the nature of the pollutants and their health effects, people could tolerate relatively high levels of them without any adverse effects. So, for certain pollutants, perhaps a daily monitoring would be sufficient. With other types of pollutants, we would almost have to have instantaneous and continuous monitoring. A good example of this is pathogens.

COMMENT: Dr. Dean, AWTRL, US-EPA, Cincinnati, Ohio. The program you set up sounds like a very good food engineering plant for making excellent water. I like your fail/safe program. I just want to know why such a program shouldn't also apply to any water supply that is polluted, because the same pollutants are present in concentrations which are not significantly less. By that I mean less than ten percent of what you've got in wastewater. So there must be a reason why it is not necessary to have a fail/safe water supply but it is necessary to have fail/safe reuse water. But the reason escapes me.

RESPONSE: Mr. Bellanca, Virginia Water Control Board, Richmond, Virginia. That's a very excellent comment. It was one that was considered at some length by the committee. As a matter of fact, Denny Parker and I had a long conversation over breakfast this morning on that same subject. It is our feeling that as the requirements for potable reuse become a little bit more widely disseminated, you might begin to see some changes in attitudes with respect to wastewater and water treatment.

We did take this into consideration, but in a different manner: by looking at the present-day raw water system, such as EPA is doing now, to determine whether or not these contaminants are reduced through conventional treatment. It is in this sense, that we make our recommendation. But I do agree that we should be looking, along the same lines, at the fail/safe reliability of our present systems. One key problem appears to be the motivation of the people behind the systems, and today that is seriously lacking.

COMMENT: Shuval, Director, Environmental Health Laboratory, Jerusalem, Israel. I fully support Dr. Dean's point, and I think, since this has come up continuously through the meeting, that the editors of the final report would be well-advised to state in the preamble that many of the treatment reliability and effluent quality control recommendations, toxicological study recommendations, and treatment technology should apply as well to any form of indirect wastewater reuse. It was not the intention of the people sitting here to imply that this technology is restricted solely to direct or overt reuse.

I think this is something that is going to come up constantly, and I think that Dean's point should be expressed by the editors of the final report, although it may not have been said in any particular document.

I told you that a good example of this was the Amsterdam meeting where we actually changed the name of the meeting when we all agreed that everything we said there applied just as much to drinking Rhine River water, which was fifty percent wastewater, as to the effluents at Rotterdam which is a hundred percent wastewater and might be diluted fifty percent with some other water.

So I think that this is an editorial point that should go all the way through the report.

RESPONSE: Mr. Bellanca, Virginia Water Control Board, Richmond, Virginia. Very well taken.

COMMENT: Mr. Spitzer, AWWA Research Foundation, Denver, Colorado. You mentioned the need for research, for example, into maintenance and all this fancy equipment. Actually, I think we've already got that technology through NASA, and the petro-chemical industry. Instead of duplicating their research we ought to do a little borrowing.

RESPONSE: Mr. Bellanca, Virginia Water Control Board, Richmond, Virginia. That's a very good point, Mr. Spitzer. Of course, I remember it was said in the very beginning that not all of us know the complete availability of things. It is comments such as yours that would help to identify where there are needs such as this and where there are techniques available.

COMMENT: Mr. McCabe, Criteria Development Branch, Water Supply Research Lab., EPA, Cincinnati, Ohio. I think the water industry and the state regulatory agency have really done what Mr. Dean suggested. The great bulk of water supplies are rather small and use groundwater supplies. In the design of these supply systems there is really little opportunity for problems. You know, you set your well for ground water and what can happen? So we really have developed some fail/safe concepts, because we don't allow small communities to go on surface water supplies. Ground water systems are more reliable. Admittedly, we do get some outbreaks. But at least we have tried not to have complex systems in small towns.

COMMENT: Mr. Ongerth, California Department of Health, Berkeley, California. I think I made the point earlier that three-quarters of my efforts are in controlling domestic water supply. I emphatically agree with what is being said, and I think we are wasting time to continue beating this horse. The waterworks industry generally understands the need for greater reliability, and certainly the regulatory people are focused on this all the time. Let's to on to another point.

QUESTION: Mr. Gallowin, National Bureau of Standards, Washington, D.C. I wonder if you had addressed in your considerations a simplistic approach of meeting your requirements for whatever concentrations may be allowed through a simple blending operation of reprocessed wastewater with "good" water blended at some point. Or is that implicit in some of what you have presented?

RESPONSE: Mr. Bellanca, Virginia Water Control Board, Richmond, Virginia. Mr. Gallowin, we did not address the actual scheme itself since we did not know which ones to consider. That we felt was the work of another group. That is a possibility, yes.

WORKSHOP ON RESEARCH NEEDS FOR TREATMENT FOR POTABLE REUSE

Chairman: Franklin D. Dryden,
County Sanitation Districts of Los Angeles County
Vice-Chairman: Carl A. Brunner, Environmental Protection Agency, NERC
Cincinnati, Ohio

INTRODUCTION

The work group on treatment found it difficult to discuss the assigned topic without benefit of the views of the reliability, quality control, and health effects work groups. However, with full recognition that we were working in a vacuum, the group proceeded to identify ten specific research needs related to treatment for potable reuse. The highest priority was assigned to the task of assembling and operating demonstration facilities of from 0.5 to 1 mgd scale capacity in different parts of the country. These would utilize four treatment trains, as depicted in Figure 1, and their variations. These treatment trains should be applied to industrial wastewaters, domestic wastewater, and substantially polluted river waters. As elaborated in the detailed description of needs, these facilities would be used to characterize the efficiency of performance of each treatment train with regard to relevant quality parameters, costs, energy requirements, by-product production, residual waste disposal problems, and overall reliability.

The other areas of high priority include developments of the use of chemical oxidants for the removal of trace organics and effective fail-safe disinfection systems, which do not create hazardous by-products and which will provide residuals in water distribution systems. Where time allowed, rough cost estimates were provided for some of the following needs. Although all of the needs were believed to be important and part of a comprehensive program, which is estimated to cost about $5 million per year for the next ten years, priorities have been assigned to indicate the relative importance of the various needs or portions thereof.

1. TREATMENT CHARACTERIZATION STUDIES

A. Characterize Effectiveness of Alternative Treatment Systems for Removal of:

		Priority
a.	Organics	High
b.	Trace metals	Medium
c.	Nitrogen	Medium
d.	Bacteria	Medium
e.	Viruses	High
f.	Parasites	Medium
g.	Aesthetics	Low
h.	Suspended solids/ turbidity	High

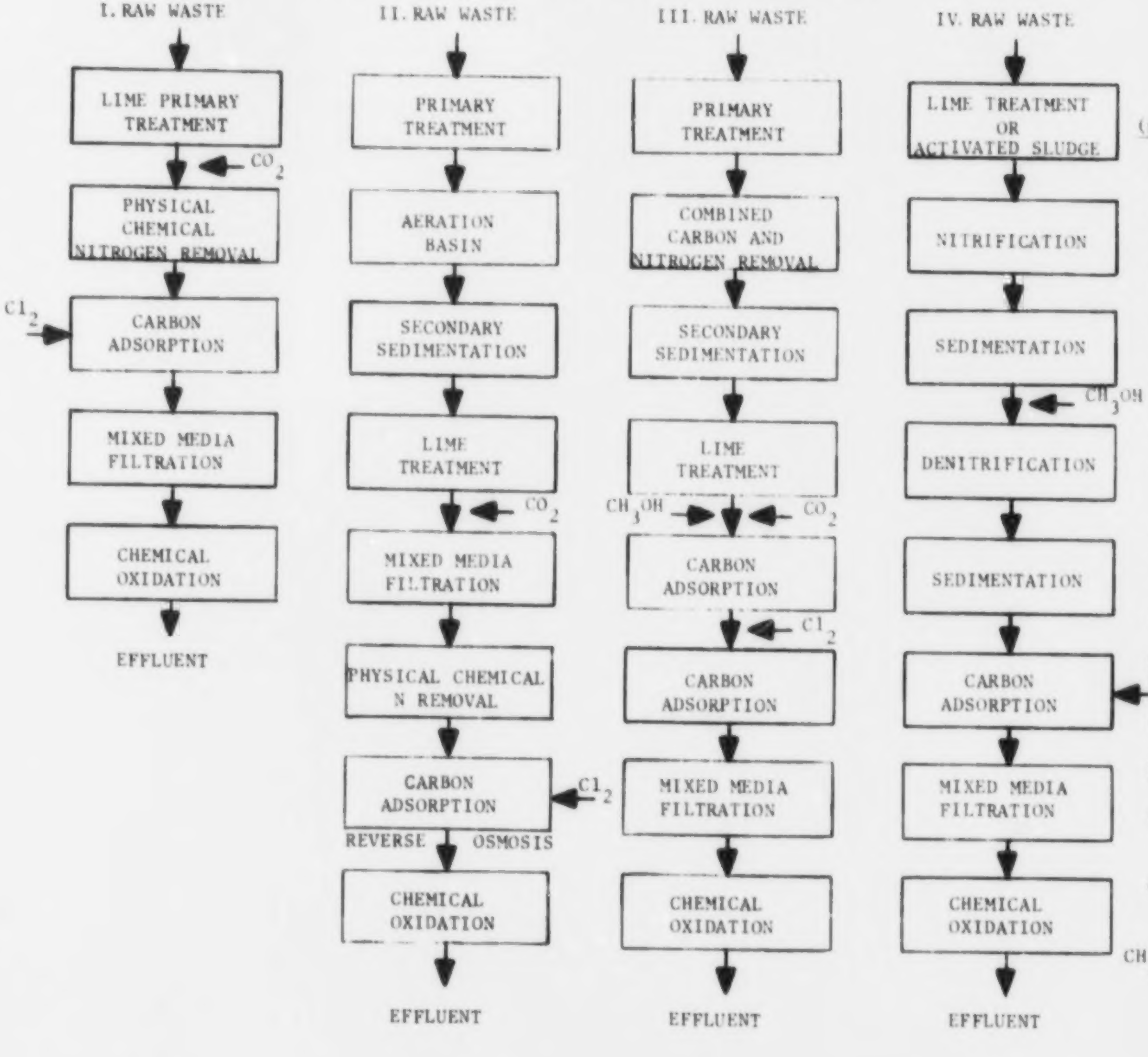
With Regard To:

a. Efficiency
b. Energy requirements
c. Costs
d. By-products
e. Reliability
f. Residual wastes and solids disposal

Discussion

The identification of the specific pollutants in the final product and the characterization of the removals performance of the individual processes within the treatment system are needed to interpret the results of health effects studies. In addition, knowledge of individual pollutant characteristics and the capability of the individual processes to remove them will help establish intelligent source

FIGURE 1. VARIOUS POTABLE WATER TREATMENT PROCESS TRAINS


I. RAW WASTE
LIME PRIMARY TREATMENT
CO_2
PHYSICAL CHEMICAL NITROGEN REMOVAL
Cl_2
CARBON ADSORPTION
MIXED MEDIA FILTRATION
CHEMICAL OXIDATION
EFFLUENT
II. RAW WASTE
PRIMARY TREATMENT
AERATION BASIN
SECONDARY SEDIMENTATION
LIME TREATMENT
CO_2
MIXED MEDIA FILTRATION
PHYSICAL CHEMICAL N REMOVAL
CARBON ADSORPTION
Cl_2
REVERSE OSMOSIS
CHEMICAL OXIDATION
EFFLUENT
III. RAW WASTE
PRIMARY TREATMENT
COMBINED CARBON AND NITROGEN REMOVAL
SECONDARY SEDIMENTATION
LIME TREATMENT
CH_3OH
CO_2
CARBON ADSORPTION
Cl_2
CARBON ADSORPTION
MIXED MEDIA FILTRATION
CHEMICAL OXIDATION
EFFLUENT
IV. RAW WASTE
LIME TREATMENT OR ACTIVATED SLUDGE
NITRIFICATION
SEDIMENTATION
CH_3OH
DENITRIFICATION
SEDIMENTATION
CARBON ADSORPTION
Cl_2
MIXED MEDIA FILTRATION
CHEMICAL OXIDATION
EFFLUENT

VARIATIONS
(many possible)

RESIN SORPTION FOLLOWING CARBON
REVERSE OSMOSIS

TWO STAGE LIME FOR SOFTENING

ION EXCHANGE

ULTRAFILTRATION FOLLOWING FILTRATION

DISTILLATION

INCLUDING IN EACH

EFFLUENT STORAGE

DISINFECTION

MULTIPOINT COAGULATION ADDITION

KEY

Cl_2 = Chlorine for residual ammonia removal
CO_2 = Carbon dioxide for recarbonation
CH_3OH = Methanol for denitrification (or other N-organic)

control programs as well as potentially lead to process improvement and new process development. The data from the characterizations will also provide knowledge of process performance variability and reliability. The data from the characterization also may identify key constituents and variables for indicator monitoring and process control.

Without the characterization studies, widespread application of direct reuse is unlikely. Finally, improved process characterization will aid in developing design and cost data for selection of cost effective systems in specific site applications.

B. Alternative Treatment Systems Deserving Evaluation: (High Priority)

Based upon experience to date, it is believed that the four treatment trains shown on the attached figure hold the potential for reliably producing potable quality water from raw (primarily domestic) wastewater. There is a need to evaluate these systems in terms of the parameters listed under 1A above. The intensive characterization period will require at least three years, plus any further time needed for evaluation of health effects. Each facility should be demonstrated on at least a 0.5 mgd scale to establish performance credibility. They should be applied to municipal wastewaters, domestic wastewaters, and polluted river water.

System I is an independent physical-chemical process. System II is a secondary-tertiary process. System III is similar to System II except that the bulk of the nitrogen is removed in the initial one-step biological treatment stage. System IV is an integrated chemical-biological treatment system. Rough cost estimate (1975 dollars): $3,000,000 construction cost per system. Analytical and operation costs (excluding health effects): $800,000 per year per system.

2. DEVELOPMENT AND/OR IMPROVE SUITABLE DISINFECTION PROCESSES AND EVALUATE THESE TECHNIQUES TO UNDERSTAND THEIR BENEFITS AND ADVERSE IMPACT:

Discussion

Disinfection is a mandatory requirement for potable wastewater reuse to insure protection of the public from infection. Unlike health hazards resulting from chronic toxicants, where the effect results from low-dose, long-term exposure, the impact of pathogenic organisms cannot always be moderated by dilution or blending. This requires the disinfection process to have a higher degree of control and reliability with essentially no allowance for short-term process failure. The generation of toxic by-products during the disinfection process, notably, but not restricted to, chlorine, is reducing the options for providing disinfection in a safe manner and possibly creating the requirement for new alternative processes. Many of the specific research requirements are shared by those in water supply and effluent treatment as well as those investigating oxidizing processes for trace organic removal. These overlapping concerns further justify the high priority placed on this research need.

Four subcategories were identified to better direct the research needed in this area. Their relative priorities were also defined.

A. Examine the By-Products of all Candidate Disinfection Processes: (High Priority)

Various techniques for water disinfection, especially chlorination, produce reaction by-products of known or suspected adverse health impact. These by-products must be identified for all candidate processes so that the consequences of the processes' use can be fully evaluated and understood. First priority should be given to chlorine, ozone, and ultraviolet-catalyzed ozone processes, but other alternative disinfection processes should not be ignored, especially if discouraging results are obtained for the above processes. Alternative processes could include the use of bromine, chlorine dioxide, ultraviolet light, ionizing radiation, and other oxidizing processes. This program could be most effectively conducted in close coordination with health effects research studies.

B. Identify Safe Residual Disinfection Alternatives: (High Priority)

Known unit processes that combine disinfection with trace organic reduction or removal do not impart a disinfection residual to the product water. A residual appears necessary for product assurance and public acceptance. The use of chlorine for this purpose may be acceptable if the trace constituents that are the precursors for toxic by-products are eliminated or reduced to an acceptable level. The identification of an alternative process, possibly involving new technology, appears worthwhile to raise confidence in the safety of the product water. This research need is especially shared with those in water supply research and requires close coordination and transfer of technology.

C. Identify Best Point(s) for Application of Disinfectant in Treatment Chain: (Medium Priority)

The utilization of a disinfection process for a dual purpose (use of ozone for disinfection and trace organic removal) may make it desirable to place it earlier in the treatment chain. Due to the protection by solids, this reordering may diminish the disinfection effectiveness at the expense of increased organic removal. Any efforts on the reordering of such dual purpose processes should include verification that no significant reduction in disinfection is created. This evaluation should also include an evaluation of the processes' susceptibility to shock loading or process failure in its new location.

D. Improve the Application of Disinfection Technology: (Medium Priority)

Disinfection, as commonly practiced (primarily chlorination), can be significantly improved through the application of improved mixing and contact technology. This effort may be insuring that the technology transfer of new methods are provided to those responsible for wastewater reuse. A relatively small continuing research effort is warranted to insure the principles developed for chlorination are appropriate or need improvement when alternative disinfectants are used.

3. NEED TO IDENTIFY AND VALIDATE INDICATORS OF SYSTEM PERFORMANCE FOR:

	Priority
a. Quality Control	High
b. Process Control	High

Discussion:

This need is considered high priority because item (a) is necessary to permit performance monitoring without an overburdensome analytical load, and item (b) is necessary for reliable and cost-effective operation.

Physical, chemical, or biological measurements which are easy to make routinely and which are predictive of incipient contaminant penetration are necessary. In addition, techniques to measure process operating parameters and control strategies to permit a manipulation of these parameters in response to input or output variations are necessary.

Examples might include TOC monitoring of carbon columns; turbidity, trace metal and chlorine residual for virus inactivation, pH control for trace metal reduction, indicator organisms more resistant to disinfection than viruses, etc.

Scope:

Laboratory analysis of pilot plant operations for three years and 40 man-years.

4. NEED FOR ADEQUATE PROCESSES FOR TRACE ORGANIC REMOVAL:

Discussion:

Present technology for organic removal results in product waters containing approximately 1 to 2 mg/ℓ total organic carbon. Although it has not been determined that there is a health hazard to this organic residual, there is likely to be a need to remove the materials to somewhat lower levels. Specific potential methods for removal include:

a. Chemical oxidation - including ozone and/or hydrogen peroxide with and without ultraviolet activation and others.

   The first step should be laboratory scale testing of the methods on appropriate feed water to determine technical feasibility. A one-year effort at $150,000 is reasonable. Pilot and demonstration work would follow for feasible methods. Cost for piloting each successful method would be approximately $100,000. (High Priority)

b. Resins - Small scale testing of appropriate resins in continuous contactors is needed. Approximate research cost is $100,000. Any successful candidates should be pilot tested to determine long-term effects. Approximate cost would be $100,000 per pilot. (Medium Priority)

c. Membranes - Small scale continuous testing is the minimum required. Minimum cost is $150,000. Pilot testing of promising systems would cost about $150,000 per pilot. (Medium Priority)

d. Volatile stripping - Initial test-can be carried out as a $50,000 laboratory effort. If pilot testing is indicated, a study could be conducted for $250,000.

e. New methods - Ideas for removing the trace organics should be solicited from appropriate sources. A feasibility study of a new method can probably be carried out for $100,000. (High Priority)

5. NEED EFFECTIVE AND ECONOMICAL PROCESSES FOR REMOVAL OF SELENATES, ARSENATES, CHROMATES, AND MOLYBDATES:

Discussion:

Although processes are available for removing many of the trace metals of concern from wastewater, the above ions are not well removed by most of the processes common in AWT. There is need for further study of possible removal processes to either remove these with other materials in the AWT process train or to permit pretreatment to enhance their removal. Effort: 2 man-years Cost: $100,000. (Low Priority)

6. EVALUATION AND IMPROVEMENT OF PROCESSES FOR DEMINERALIZATION IN ORDER TO

   a. Reduce costs.
   b. Reduce energy requirements.
   c. Utilize beneficial side effects.

AND IN PARTICULAR TO DEMONSTRATE ION EXCHANGE IN RENOVATION SYSTEMS:

Discussion:

In some areas of the nation, the salinity of renovated water can militate against its use, not only for domestic (potable) reuse but also for lower grade uses in industry or agriculture.

The salinity can arise from the initial salinity of the natural water, from saline inputs during use, and from infiltration of saline groundwater into the sewage system.

In systems where new water is of low salinity and makeup exceeds 50%, salinity should not be a problem. However, in a large system, it may not be geographically feasible to redistribute the saline-renovated water equally over the whole system so that local concentrations may rise. In such cases, partial desalination to scalp a proportion of the salts may be an economic tool for water management.

Desalination, utilizing ion exchange resins, reverse osmosis membranes, or distillation will also have beneficial effects on the removal of the other pollutants in the treatment train. For example, toxic metals, some organisms, and nutrients including nitrates may be removed in the course of desalination. Reduction of hardness of renovated water may be a benefit for domestic use.

Suggested Approach:

Test on laboratory scale new demineralization processes with potential for significantly reducing costs or energy requirements using waters from operating treatment plants. Demonstrate the most cost-effective ion exchange technology.

Scope:

Probably two to three years. Laboratory scale, increasing to 10,000 gpd pilot plant where justified. Demonstration of the best techniques: $750,000. Demonstration of ion exchange: $750,000. (Low Priority)

7. NEED TO EVALUATE STORAGE STRATEGIES WITH RESPECT TO AWT AND POTABLE REUSE:

Discussion:

Two essential factors in reuse - quantity and quality - are impacted by the concept of storage.

With respect to quantity, storage again reflects upon two different needs, that within the plant and that before or after the reclamation facility. In most cases, steady state performance can be expected from the reuse plant with its ability to choose and withdraw required amounts. Flow equalization can reduce diurnal and seasonal flow fluctuations if needed.

Within the plant, however, storage appears essential before filtration and perhaps carbon treatment or demineralization because of erratic recycled streams. In-plant ballast ponds serve a dual purpose as an emergency holding facility for bypassed flow and as buffering capacity.

Post plant ponds may serve as a buffer for required water demands. Covered storage is essential for quality control.

In terms of quality, storage can average out concentration peaks before the AWT plant and allow detention time to reduce biological contaminants.

If a poor quality effluent is the feed to the reclamation plant, storage may or may not enhance quality. In some cases additional pretreatment may be necessary. Extended storage may result in growth of undesirable organisms.

The main concern is finding the least costly method of providing the storage since the benefits of flow equalization and product protection are clearly evident.

The research ranks low in priority and is being studied in the entire AWT and sewage treatment field. It deserves research funding but perhaps not in terms of potable reuse.

A good part of the evaluation can be performed on paper with only limited testing to ascertain whether there are problems associated with any particular storage mode.

8. DEVELOP AND DEMONSTRATE LOW-ENERGY NITROGEN REMOVAL PROCESSES:

Discussion:

Nitrogen removal will be required in the treatment of wastewater for potable reuse. Currently available physical-chemical and biological nitrogen removal processes use large amounts of energy to remove a substantial fraction of the nitrogen present in wastewater. Combining the processes of removing carbonaceous and nitrogenous materials in a single-stage biological reactor offers the most promise of removing 70- to 90% of the nitrogen present and, at the same time, substantially reducing the total energy expended. In this process, the organics present in the wastewater supply the source of carbon for denitrification and eliminate the offsite energy consumption in methanol production. Other means of reducing energy consumption in nitrogen removal processes should be investigated.

Suggested Approach:

Construct a 100,000 gallon/day demonstration plant and operate for one year. Seek innovative low-energy alternatives for bench scale testing. Cost of project: $500,000. (Low Priority)

9. DEMONSTRATE STABILIZATION/RECOVERY/DISPOSAL OF RESIDUALS RESULTING FROM ALTERNATIVE TREATMENT SYSTEMS DELINEATED IN 1B: (High priority overall but low priority specifically for potable reuse)

Discussion:

Research is to insure the availability of adequate and economically viable control options for the accumulated residuals emanating from treatment processes related to potable reuse. The problem area is not unique for the potable reuse problem but necessarily is a guidelines factor for eventual implementation of specific treatment schemes.

Approach:

1. Determine nature of residuals emanating from alternative treatment systems.
2. Nominate methods for controlling residuals.
3. Verify economic viability through engineering scale demonstrations of control methods.
4. Make sure land stabilization alternatives are considered.
5. Apply residual control criteria to overall viability criteria of alternative treatment systems.

Length of Study:

Major activity requiring time allocation is demonstration. This should be long enough to assess residual variation and control technology stabilization on the order to two to four years. Costs: Pilot studies in conjunction with alternative treatment systems in the amount of $250,000 per year per pilot facility.

10. AN EVALUATION OF THE CHANGES IN WATER QUALITY RESULTING FROM STORAGE AND MOVEMENT OF TREATED WASTEWATERS THROUGH THE GROUND:

Discussion:

Several of the present and potential systems for treatment and planned reuse of municipal wastewaters for potable water supply involve percolation or injection of the treated water into groundwater aquifers. The storage time, movement, and intermingling with naturally occurring groundwaters may result in substantial improvement in quality and safety of the water. However, information on the kinds and extent of improvement, which may result, is lacking. Research is needed to determine what levels of improvement can be expected and to establish what characteristics of injected or percolated waters lead to maximum improvement in water quality and minimum reduction in the permeability of the groundwater aquifer.

Workshop Participants:

Dolloff F. Bishop, U.S. EPA, National Environmental Research Center, Cincinnati, Ohio.

James R. Boydston, U.S. EPA, Corvallis, Oregon.

Carl A. Brunner - Vice-Chairman, EPA/NERC, Advanced Waste Treatment Laboratory, Cincinnati, Ohio.

John J. Convery, AWTRL, U.S. EPA, Cincinnati, Ohio.

Franklin D. Dryden - Chairman, Sanitation District of L.A. County, Whittier, California.

Don Felke, Tertiary Plant Foreman, Colorado Springs, Colorado.

Daryl Gruenwald, Wastewater Treatment Superintendent, Colorado Springs, Colorado.

Carl Hamann, Cornell, Howland, Hayes & Merryfield, Inc., Reston, Virginia.

Richard D. Heaton, Denver Water Department, Denver, Colorado.

Denny S. Parker, Brown & Caldwell, Walnut Creek, California.

Stanley Smith, Water Division, EPA, Denver, Colorado.

Albert Soukup, U.S. EPA, Denver, Colorado.

Richard L. Woodard, Camp, Dresser & McKee, Inc., Boston, Massachusetts.

DISCUSSION

COMMENT: Mr. Spitzer, AWWA Research Foundation, Denver, Colorado. I am a little bit disappointed because you have given aesthetics a low priority. Take, for example, taste and odors. We have trouble selling some of our products now because of taste or odors, and we certainly haven't solved these problems. If we have trouble selling something that is taken from a rather good source, after you go through all of the other removals (and they are certainly important), if you can't sell it, there is no use going through that. I think that should certainly be rated high.

RESPONSE: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. We recognized that that might cause some controversy. I think it reflects the general confidence of the group that by the time we went through the treatment chains that we are talking about, the research problem of taste and odors was not going to be high priority, and that these systems were in fact, capable of handling the taste and odor problem. We do think it is a problem that needs to be looked at. Should it turn out to be a real problem, obviously it would have to be given attention. But I think the low priority simply reflects the feeling that the process chains that are described herein can actually handle the components that would contribute to the taste and odor problem.

COMMENT: Mr. Jack Glennon, U.S. Army Medical Research Development Command, Washington, D.C. Another thing is that the priorities on this first page more or less describe the level of effort that would be required in the validation study. In other words, more samples should be taken for organics and less for taste and odor. That being a relatively easy parameter to measure, you can get better reliability on it with less effort involved in the sampling.

QUESTION: Mr. Robert G. Tardiff, EPA/NERC, Cincinnati, Ohio. You have discussed the removal of selenates, arsenates, chromates, and molybdates. I would be interested to know why you restricted that to one valence form.

RESPONSE: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. Would Dick Woodard like to speak to that?

RESPONSE: Mr. Richard L. Woodard, Camp, Dresser & McKee, Inc., Boston, Mass. I think the feeling was that lower valence forms of these materials are much more readily removable by conventional processes than the higher valence forms.

COMMENT: Mr. Tardiff, EPA/NERC, Water Supply Research Laboratory, Cincinnati, Ohio. I don't know how good that is going to be, though, if the other valence forms are more toxic. If the other valence forms are more toxic, what good is it going to do to remove arsenate if you have arsenite left behind? Is that what you said here?

RESPONSE: Mr. Woodward, Camp, Dresser & McKee, Inc. Boston, Mass. No. I said you can take out arsenites fairly readily with some of the processes that are listed here.

COMMENT: Mr. Tardiff, EPA/NERL, Cincinnati, Ohio. Down to the real low levels? At the present time, the efficiency of removal is not that great. The kinetics are such that you don't remove it down to the part per million level.

RESPONSE: Mr. Woodard, Camp, Dresser & McKee, Inc., Boston, Mass. Of course, it depends on where you start. Only in a very few situations are these materials present in relatively significant concentrations. This normally occurs in certain natural groundwaters rather than in wastewaters. One reason that this is in for a low priority is that it does not seem to be much of a problem in wastewaters as a rule.

QUESTION: Mr. Francis M. Middleton, EPA/NERC, Cincinnati, Ohio. While you have mentioned monitoring and instrumentation in this presentation and in the previous one, did anyone give any consideration to the level which we are now at in terms of ability to measure and monitor the important things? Do we have to have a $50 million instrumentation program or are we halfway there? I imagine you didn't have time to get deeply into that. I think maybe it's a deficiency in our program here that there isn't more consideration of measuring the state of the art. But did you consider that?

RESPONSE: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. We did not talk a great deal about monitoring because we felt that was in the domain of the reliability group and we were instructed to try to stay out of their domain. Obviously, monitoring and instrumentation are extremely important parts of this. I would say that the kind of budgets we are proposing would probably have some money there for efforts of that type. But we did not try to conceptualize the monitoring problem.

QUESTION: Mr. Middleton, NERC, U.S. EPA, Cincinnati, Ohio. Did Mr. Bellanca get into that?

RESPONSE: Mr. Bellanca, Virginia Water Control Board, Richmond, Virginia. Not in that detail.

COMMENT: Moderator Convery, AWTRL, U.S. EPA, Cincinnati, Ohio. We did have in both workshop sessions the concept of indicator monitors which was not as a result of the characterization studies but the concept of trying to find which breaks through earlier on carbon.

COMMENT: Mr. Roesler, EPA/NERC, Cincinnati, Ohio. I would also like to add to John Convery's comment about the indicator parameters. Our philosophy toward the indicator parameters was that we felt that many of the conventional parameters that are used to monitor wastewater streams or drinking water streams are unsuitable for automation, such as carbon-chloroform extracts and BOD_5. The time taken to run these samples is too long. By the time you get an answer, the water is already in the distribution system. So we felt that a program should be developed to determine new indicator parameters; perhaps something along the line of E. coli to indicate bacterial pollution in the streams.

RESPONSE: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. I believe there is some feeling in our group that a sensitive, continuous TOC analyzer may be fairly close at hand, but we really didn't get into that.

COMMENT: Mr. Roesler, EPA/NERC, Cincinnati, Ohio. You see, the problem with the TOC is that it is not accepted by all the states as a reliable indicator of pollutants coming in or leaving the plant.

COMMENT: Ms. Gorchev, EPA, Washington, D.C. I like very much the idea of giving cost estimates, and your total amounts to about $9 million. I guess that takes care of Mr. Rosenkranz's budget.

RESPONSE: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. We did not operate with the constraint that we were going to have to do the research within existing budgets. I think if you start with that presumption, we're through now and we don't have to continue. The fact is that we are talking about a program that deserves a research effort of significant proportions, and we trust that this workshop will be a step in defining that need in a way which ultimately will lead to proper funding of a program of this type.

COMMENT: Ms. Gorchev, EPA, Washington, D.C. I was just thinking that for the other research needs, you people in treatment have had a headstart anyway. So for the other workshop estimate, this might be at least double or triple per year.

QUESTION: Mr. Schmidt, SCS Engineers, Long Beach, California. I have wondered where the existing advance waste treatment facilities fell into your plans. I see a lot of similarity between many of your treatment chains and those at Tahoe, Orange County, and so forth.

RESPONSE: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. The question of where you perform a particular study or train would take into account where there are existing facilities. I am sure that an attempt would be made to utilize existing systems where applicable. I don't think that the trains we have envisioned are precisely in production anywhere at the present time. Components of the systems that we are talking about have been tried, and at least on a very small scale, there is some knowledge about almost all of them. But we would like to see them demonstrated on a large scale. We would hope that the cost can be reduced if they can be integrated into existing advance waste treatment efforts.

Sometimes you have constraints in that the existing programs are designed to perform a particular task right now and they are not really available for research evaluation. That type of problem has to be taken into account. You can't go in and change the variables on an existing production-type program in order to produce our results. If the existing plant has a different set of objectives that they have to meet, their objectives are going to govern what happens. Those situations, obviously, would need to be investigated as you decide where and how to put these chains into test conditions.

QUESTION: Mr. B. Cees J. Zoeteman, WHO International Reference Centre for Community Water Supply, The Hague, The Netherlands. I think that the available treatment technology is rather limited in its possibilities in general, and, therefore, I would like to support your point dealing with new methods. Are there any specific ideas within your group of what kind of new methods could be applied in the future.

RESPONSE: Mr. Dryden, Sanitation District of L.A. County, Whittier, California. My impression would be that when we say "new methods," we are thinking about things people have not thought of yet and, therefore, they are not in their minds at the present time.

QUESTION: Mr. Middleton, NERC, U.S. EPA, Cincinnati, Ohio. I would like to hear Fred say a few words about the hope for catalytic oxidation for that last bit of pollution we are going to worry about. He's working in that area.

RESONSE: Mr. Fred Bishop, U.S. EPA, National Environmental Research Center, Cincinnati, Ohio. Frank is referring to a system to be used to remove the last trace of residual organics. For this one needs a very potent oxidant which would not tend to produce residual components which are incompatible with our biological systems. The best hope for this is probably in the single electron peroxide pathways or molecular oxygen oxidation sequences which are called free radical oxidation. The most potent oxidant available in this particular area is the hydroxyl-free radical. That particular radical will abstract hydrogen from any carbon-hydrogen bond. It has the potential, therefore, of totally destroying organic residuals in the water.

Since the amounts of organic residuals are relatively low, one can afford to put in excess amounts of these oxidants and, thereby, potentially destroy most of the residual organics. Of course, the problem of doing it is related to the means of generating the hydroxyl radical or the actual hydroxyl species within the water. One of the ways of doing this is with ozone. Ozone, will serve as a conventional oxidant, by itself, but with a suitable catalyst, such as ultraviolet light, it will also go the free radical route and will cause additional destruction of the residual organic components. Of course, there are the cost considerations of getting the ozone and the ultraviolet into the water.

A second approach could involve the use of hydrogen peroxide with ultraviolet light or a peroxyl catalyst. Each of these will generate the free radicals which will attack the residual organics. Now whether we can go all the way down or how far we can go in eliminating residual organics hasn't really been determined, but I think the possibility is quite strong that we will be able to do a very good job. The kind of residual components that are left with the oxygenated organics are relatively high oxygenated organics. Hopefully these would be considerably less toxic in the chronic area than the chlorinated compounds.

We have an engineering problem of putting the necessary oxidant into the aqueous solution. However, this may not be as tough as it might appear on the surface.

WORKSHOP ON HEALTH EFFECTS OF POTABLE REUSE ASSOCIATED WITH INORGANIC POLLUTANTS

Chairman: John R. Goldsmith, National Institutes of Health, Cancer Institute
Vice-Chairman: Gunther F. Craun, Environmental Protection Agency, WRSL
Cincinnati, Ohio

GENERAL PRINCIPLES

1. Research on this topic is intimately related to other environmental health research, and especially to that relevant to drinking water criteria for standard setting. This research is also related to ongoing studies and to that on categorical diseases such as cancer, heart disease, and to geographical gradients in morbidity and mortality.

2. Given data on occurrence of materials in water, a balanced use of epidemiological and toxicological research is necessary. It is reasonable to assume that in different communities different constituents will be present - hence a responsive system of research studies will be needed.

3. A general epidemiological strategy would include epidemiological work on water constituents along with other broad-scale, long term epidemiological work. A general toxicological strategy would be based on population - dose estimates and on indices of mixtures tested in model systems such as cell cultures, and in other more conventional experimental procedures.

4. Results of such research should contribute to criteria for inorganic constituents, through open scientific review and if the data are sufficient, the data may be used to set standards. The standards may and should reflect feasibility, cost, and other considerations than health.

5. Research on Occurrence. Some materials have optimal levels of ingestion or in water supplies, levels which are either not harmful or may be beneficial. An objective of the research program is to classify occurrence by concentration into zones which indicate the level of health concern (or benefit).

DETAILED PROPOSALS FOR STUDIES

1. A. Local Variations in Occurrence in Communities with Varying Proportions of Reused Water.

Determine those specific geographic areas where use of reclaimed water for potable use is most imminent. Examine the waste streams from those, or selected similar, areas to determine the presence and concentration of inorganic (and organic-metallic) substances which are not currently included in the drinking water standards.

There is also a need to compile and/or analyze the influent and effluent from existing pilot or actual reuse situations to determine the occurrence of inorganic constituents. Samples should be collected at representative taps to reflect actual exposures of water supplied, including the effect of distribution materials. Wastewater treatment may produce an unstable water which could be corrosive to distribution piping. As new technologies are introduced and used, various products will find their way into wastewaters. In light of this, studies of occurrence of materials released by new technology into wastewater should be part of the national technology assessment process.

B. Multi-elemental Analysis.

Use of multi-elemental analytical techniques such as spark source mass spectrometry, x-ray, fluorescence and emission and neutron activation, etc. should be encouraged to document the occurrence of inorganics in water and wastewater for reuse. Research is needed in perfecting sample preparation techniques, and in increasing the sensitivity, accuracy and precision in this area. Application of these techniques can be used for epidemiologic studies and body burden studies (hair, nails, blood) to assess the occurrence of inorganic contaminants in the general population also.

Compounds such as NO_2 and NO_3 and constituents such as asbestos which cannot be determined with multi-element techniques should be determined as appropriate.

C. Characterization of Organometallic Compounds and Metal Chelates.

Such materials are widely used in industry and have a high probability of occurrence and buildup in wastewaters. Little is known of their health effects.

Identification of such organometallic components in wastewaters is difficult. Existing analytical techniques are available in chemical engineering and industry.

Examples include alkyl and aromatic amines and dicarboxylic acid compounds (components having available electrons for sharing with electron deficient components).

The inorganic counterparts generally are the electron deficient cations of metals capable of forming complexes with electron rich organic components or chelates. Cations of cadmium, lead, magnesium, calcium, strontium, barium, nickel, copper, tin, cobalt, iron, and manganese, are a few that are possible.

2. Body Burden-Introduction

Body burden estimates can be thought of as a first step in a continuum of effects. The later or more serious steps occurring with greater exposure are: a) impairment of function or performance, b) aggravation of disease and c) causation of new disease. For many contaminants evidence of causation of disease has required long exposures, large numbers of persons, and the passage of many years. Body burden changes can be detected much more readily and much earlier (i.e. with less exposure) than manifest toxicity. This has been shown, for example, for lead and cadmium. Hence a greater level of health protection is implied by protection against increased body burden than would occur if one awaited more serious effects.

In some cases, an increase in body burden, in the absence of other effects of a substance, indicates only a biological interaction with the substance. In other cases, the body burden increase may signal the onset of impairment or disease.

A. Use of Autopsy Studies to Determine Human Body Burden.

Where cities are known to have differences in water constituents, autopsy, placental tissue, or surgical specimens may show that different water constituents lead to different concentrations of these same constituents in target organs. In addition, such data may make it possible to relate high levels of storage to morbidity and mortality from various causes. Samples generally used as body burden estimates (hair, blood, etc.) in living populations should be compared to the appropriate organ or tissue (liver, kidney, brain, bone, etc.) which can only be sampled in autopsy studies.

B. Population Screening for Estimates of Body Burden.

Populations consuming water of varying qualities with respect to certain contaminants can be sampled to determine whether these contaminants are taken up and stored. This would, if observed, indicate some level of biologic transport or interaction. When such studies are done, other sources of these contaminants must be controlled (e.g. occupational exposure, smoking, food, air contamination).

Body burden estimates have been based on samples of scalp hair, nails, blood, urine, subcutaneous fat, deciduous teeth. Expired air and ear wax samples have been used for other purposes but may be inappropriate for study of inorganic water contaminants.

Such determinations can be included in epidemiologic studies and epidemiologic principles should be applied in their analysis.

C. Physiological Availability of Inorganics in Water.

The mere presence of an element or compound in water need not imply that there is any appreciable uptake. For example, the material may be in an insoluble form or it may be complexed or chelated. Little is known about the role of particulate matter which may influence the uptake or bind particulates to other materials.

Both animal and human studies, along with improved physical-chemical characterization, are needed to determine the uptake fractions for various forms of inorganic constituents in water. These uptake fractions may vary with age of the subjects or with the amounts of these or other materials in the diet.

Better data are needed on water consumption extremes that occur because of occupation, age, climate.

3. Toxicological Studies

A. Use of In Vitro Methods to Screen Classes of Concentrated Toxicants Including Screening for Carcinogenesis and Mutagenesis.

It is recommended that EPA make use of a balanced application of a wide variety of in vitro and in vivo systems for the study of contaminants in water. This should certainly include several in vitro systems including bacterial and cell culture systems.

A possible strategy for the use of these systems would be as:

(1) Primary toxicity screens.

(2) Indicator systems for determining active fractions in various fractionation schemes and refractionation of the active portions.

(3) Systems for the study of the interactions of chemicals for toxicity including mutagenesis and carcinogenesis.

Such toxicity testing depends on concentrating materials in wastewaters and fractionating the concentrate according to generally accepted principles of physical affinity and biological or chemical activity.

Data exist on a variety of *in vitro* techniques that may be considered suitable for this purpose.

Animal toxicity testing should be used to validate such techniques where appropriate.

B. Animal Models of High Risk Populations.

Conventional animal toxicity studies use relatively healthy normal animals, yet the human health effects of greatest concern involve effects on infants (nitrates and nitrites) and on those with cardio-vascular diseases (sodium, hardness).

In addition, concern about mutagenesis, teratogenic effects, and effects on pregnancy outcome imply needs for study of exposures during reproduction in animals.

There are no well established relationships between results on healthy animals, and those with impairment. Accordingly study of selected types of impaired animal systems is needed if data are to be obtained which are relevant to high risk human groups.

C. Population-Dose Estimation.

The amount of a material in potable water does not necessarily relate to the amount ingested, since a high proportion of the liquid intake is from food and beverages. Food and beverage preparation may increase the concentration (by boiling) or decrease it (by adsorption, say, to tea or coffee grounds).

It is necessary for each substance and class of substance to estimate the population dose based on usual food, beverage and water ingestion.

In addition, in locations, or types of employment, with high environmental temperatures much higher intake of fluids is likely and it is often in just such locations that potable use of wastewater will be most attractive.

D. Behavioral Toxicology.

Behavioral toxicology has been shown to be a useful test system for effects of nitrites in rats. It has been shown to be a very sensitive indicator of effect for certain compounds and is probably the only way alternations in cerebral function by toxic agents can be approached in animal studies.

4. Epidemological Studies

The study of the effect of the environment upon the health of the population, i.e., epidemiology, depends upon the appropriate measurement of:

1. Various parameters of the environment, including specifically the content of the drinking water, including overt and covert reuse,
2. various measures of health effects, including age-sex-race-specific rates of mortality and incidence of disease, and
3. the relationship between these two groups of variables, properly controlling other relevant variables such as occupation, income, nutrition, smoking, altitude, etc.

In some instances economy of effort is possible by development of multipurpose studies, while in other instances, such as cancer registries, the development of local organizations, and of systematic and complete data systems along with persistent effort will be required over a period of years.

Collaborative efforts from many groups can assist in planning and conducting the needed studies. One possibility is that a commonly agreed water assessment strategy might be developed to insure that kinds and amounts of pollution and possible health reactions are measured uniformly. A small, interdisciplinary group with international support could be convened to develop and design such a strategy.

Since the W.H.O. International Reference Center has proposed such a joint effort, one mechanism for such a cooperative effort exists.

A. Relation of current-water quality to incidence and prevalence of chronic diseases.

Research is needed on the relationships of 1) content of the drinking water and 2) the age-sex-race-specific risk of death, particularly for age groups between 35 through 74 years, for all causes as a group as well as for specific causes in geographic areas for which data can be readily obtained in relation to sodium, hardness, TDS and trace metals. Comparisons of areas using polluted and clean raw water intakes should have priorities.

There are convincing statistically significant differences between geographic areas in the risk of dying under age 75. If environmental characteristics of the lowest-rate areas could be applied to "higher death risk rate" areas throughout the U.S., there would be an estimated 160,000 fewer deaths per year under age 75 (or 100,000 under age 65).

Present data relating death rates to components of drinking water including components resulting from indirect reuse of wastewaters are confused and uncertain.

Approach:

1. Obtain information on the content of the drinking water, both bulk and trace substances for metropolitan areas and cities with available data with emphasis upon areas exhibiting a wide range of death rates.

2. Calculate age-sex-race-specific death rates, all causes and cause-specific (age 35 through 74 especially) for 3 or 5 years around the 1970 census for the specific areas for which available water data exist.

3. Study the degree of association or correlation between point 1 and 2, paying due attention to the contribution of other variables. Explore methods for increasing the scientific rigor of all points stated.

B. Collection of Health Data Before and After Direct Reuse.

Rates of the incidence and prevalence of chronic disease are sought for many purposes in relation to the study of the effects of the environment upon health, including the reuse of water for potable purposes, both overt and covert. Properly designed registries may be an efficient basic tool for this purpose.

A city planning overt reuse of water will require many different types of data accurately collected and analyzed, to determine whether reuse has an adverse effect. Data should include two or more years before overt reuse and at least for several years after, on incidence and prevalence of various chronic diseases, as well as information relevant to possible acute episodes.

Registries may be either of persons with a given disease such as cancer, or of persons with a given exposure such as to potable wastewater. They are expensive and require persistent work by well-motivated individuals. In those special situations in which local people are genuinely and persistently interested in achieving goals that can be accomplished through the use of a registry and related work, it provides a potential for producing very valuable data for many purposes.

A useful population registry will probably require a minimum of 7 or 8 years to provide useful information.

C. Hypertension and Cardiovascular Disease Associations with Drinking Water.

Associations of cadmium ingestion and hypertension have been reported.

In Great Britain convincing evidence has shown the association of hardness with low rates of cardiovascular disease. The substances responsible for this association have not been clearly determined. Some of the contaminants in reclaimed wastewater may be relevant to this association.

Such studies in other countries including the U.S. have indicated the possible relevance of sulfate-bicarbonate ratios, lead, copper, magnesium and sodium. Comparison studies between otherwise comparable communities or longitudinal studies in communities changing their water supply system can assist in resolving these questions.

D. Assessing Contributions of Water Quality to Variations in Chronic Disease Rates.

Rates of the incidence of "serious" chronic disease, age-sex-race-specific vary from place to place. Presumably, this is a reflection of environmental effects of which water constituents may be one possible cause.

Areas exhibiting marked differences in chronic disease death rates are found in such locations as Boulder, Colorado and Russell County, Alabama or Cache County, Utah and Silver Bow County, Montana. These and similar contrasting geographical pairs should be utilized in determining the possible relationships between disease incidence and concentration of water constituents indigenous to each area, controlling for other relevant variables.

Serious diseases may be defined as those which are incapacitating and which nearly always require hospitalization. Such instances are found in lung cancer, stroke (exclusive of transient ischemic attacks) and acute ischemic heart disease. Present information suggests that documentation of incidence of such diseases may be adequately obtained from hospital discharge reports and death certificates when they are checked against each other to prevent duplication.

The approach eliminates the burdensome task of relying upon a physician's memory for each case study which may be very costly.

Workshop Participants:

Willard R. Chappell, Director, Molybdenum Project, University of Colorado, Boulder, Colorado.

Robert I. Christian, University of Cincinnati, Kettering Lab., Cincinnati, Ohio.

Gunther F. Craun - Vice-Chairman, EPA, WRSL, Inorganic Studies, Cincinnati, Ohio.

John R. Goldsmith - Chairman, National Cancer Institute, NIH, Bethesda, Maryland.

Hend Gorchev, EPA, Washington, D.C.

Cheng-Chun Lee, Pharmacology and Toxicology, Midwest Research Institute, Kansas City, Missouri.

Miriam Orleans, University of Colorado Medical School, Denver, Colorado.

Herbert I. Sauer, Community Health & Extension Environmental Quality, University of Missouri, Columbia, Missouri.

Rexford D. Singer, University of Minn., Minneapolis, Minnesota.

Harold Wolf, Director, Dallas Water Research Center, Dallas, Texas

DISCUSSION

QUESTION: Mr. McCabe, Criteria Development Branch, Water Supply Research Lab., EPA, Cincinnati, Ohio. John, in your proposal for studies before and after potable use of reclaimed water, did you talk about the possibility of tissue-banking before you started, so that you keep open the option to do some body burden studies as well as your morbidity collection before and after?

RESPONSE: Mr. Goldsmith, National Cancer Institute, NIH, Bethesda, Maryland. No, we didn't. It is a very good point and I think it is appropriate to add it. I think that is partly because we isolated the body burden from the epidemiologic work, which was a mistake. But we followed the classification presented in your report, Lee. So we will try to put it back together sometime.

COMMENT: Mr. Lee, Washington University Medical School, St. Louis, Missouri. Dr. Goldsmith, I would like to make a few comments about your editorial modifications to the section on the organometallic and metal chelates.

The idea here was that there is really no instrumentation for analyzing any of these compounds, and any type of work that is being done by nature will be very tedious and difficult. So if you address yourselves to organometallics, the idea was to get to know the compounds that are used throughout the industries as stabilizer or extender reinforcement. And if they make the compound, no doubt they know the chemistry of it and the structure of it. What we look for are forms that we know will be modified; i.e. oxide form, the halogenated, and the hydroxylated, and then identify them.

For the more complex forms of the metal chelates, since they are not as chemically stable, the first approximation would be to identify the chemical components that would be able to form chelates. This would be the alkyl and aromatic amines, and any type of electron-rich source that can form chelate-type lignins with cations such as those you have listed.

This is only the first approximation. It would be desirable to include not only the chemical constitutents, but a few of the chemical variables and physical variables that they are exposed to.

QUESTION: Mr. Tardiff, EPA, NERC, Water Supply Research Laboratory, Cincinnati, Ohio. In your general conclusions, the second one discussed emphasized the fact that there were differences from community to community, particularly with regard to their constituents. Later on in your text you also talk about differences in morbidity and mortality, and other disease parameters. Are you suggesting that we should be performing epidemiological and/or toxicological studies on community bases as opposed to doing generalized studies which allow us to set national drinking water standards?

RESPONSE: Mr. Goldsmith, National Cancer Institute, NIH, Bethesda, Maryland. I think the general interest and emphasis of the panel was to stress community-based epidemiological studies under guidelines that were set up nationally with support and collaboration from national resources and with a great deal of interaction with an international effort in order to make sure that there was efficiency and validity of many of the methods used.

The other reason for stressing this was because it is somewhat easier on a community basis to develop a multi-purpose application of the epidemiologic work so that it isn't necessary that all of it be supported solely for purposes of water research.

QUESTION: Mr. Tardiff, EPA, NERC, Water Supply Research Laboratory, Cincinnati, Ohio. I was trying to determine whether you are going to get data which would allow you to set community standards or national standards, and whether national standards are even warranted?

RESPONSE: Mr. Goldsmith, National Cancer Institute, NIH, Bethesda, Maryland. I think what we were concerned about is the variation between communities and the constituents in the wastewater stream. Of course, there are also potential variations in the community in the proportion of susceptibles and other factors.

I don't see any contradiction between community epidemiologic studies and their reflection on, and support of, national quality standards. I am speaking from experience in other areas but I know that, in general, the strong community studies have had a great influence in national programs and in national standards. So, I don't see that the conflict is a substantive one. I can see that it might appear to be. I think that when experience is acquired, it will be seen not to be as serious a matter as it might suggest.

QUESTION: Mr. Ongerth, California Department of Health, Berkeley, California. I am not sure I can follow the subtleties of this interchange between the two of you. Doesn't a community survey, contrasted with a control population someplace else, give you one point on a curve? For a community that is exposed to constituent $\underline{x}$ you have one point on the curve which represents the effect on community health at this level of exposure to constituent x. If you have enough communities, you have a number of points on the curve and you can extrapolate or project back down to some information that enables you to set the standards. This is an engineer's concept of toxicology and environmental epidemiology. Am I off the track?

RESPONSE: Mr. Goldsmith, National Cancer Institute, NIH, Bethesda, Maryland. A great deal depends on the nature of the study. Many of the body burden studies generate a whole curve with one study. That is, of course, very important. But in some epidemiologic studies, you get a number of points as the output because you can rank the populations by exposure in, say, seven or eight different groups and estimate the effects. Then you have seven or eight points. There are, of course, epidemiologic studies which only produce one point. But a great deal depends on the nature of the study.

COMMENT: Mr. McCabe, Criteria Development Branch, Water Supply Research Lab., EPA, Cincinnati, Ohio. John, I think in the report you did allude to the fact you were concerned that the areas of the greatest water consumption would be the areas where this reuse might take place. So, I think you may have already talked about a unique community standard and not a national standard because your consumption is going to differ.

Also, if you are going to do the community study, you will get some insight into food consumption that might be different in certain parts of the country than in others.

RESPONSE: Mr. Goldsmith, National Cancer Institute, NIH, Bethesda, Maryland. My personal preference is for the reporting of national criteria which are clearly and lucidly interpreted and give guidance to community standards. But I have no opposition whatever to national standards. I think in many cases it is the only way to go when a given material is hard to study, and when studies are few.

One of the other approaches to community variation in exposure is to take into account the environmental temperature. This, of course, has been recommended for standards related to optimal fluoride ingestion, and it is a worthwhile example to keep in mind.

COMMENT: Mr. Shuval, Director, Environmental Health Laboratory, Jerusalem, Israel. I would like to further this point relative to developing data for a dose-response relationship. I think that the workshop group dealing with the health effects of organics is going to come up with a recommendation relative to the value of international cooperative studies. I think it holds just as true at this point that if we are going to get reliable data on the response to environmental stress (in this case, water stress, organics or inorganics), we will need to choose a number of selected sites where this can be done. I think that it would be wisest to draw up a standard protocol for running such studies, which really requires very fastidious control, and then to select optimal sites with a complete range of concentration levels. This would mean using the best sites available in the world, whether they be New Orleans, Cincinnati, London, Rotterdam, or other cities throughout the world. I think that the well-designed dose-response study which is required to provide answers in the United States, should use the best available sites in the world. This would call for the type of international program that the World Health Organization International Reference Center has suggested. Their suggested program included a feasibility study to design such a series of studies followed by actual conduct of the study.

COMMENT: Mr. Gordon W. Newell, Stanford Research Institute, Menlo Park, California. I am concerned about this setting of standards in terms of health effects. Gentlemen, we are talking about the effects of materials and chemicals as toxicants, and you have to know what is specific about each one. As Dr. Goldsmith points out, in some cases you have an environmental effect which can modify the response and the tolerance that people have. You get into some areas where you have differences of pH in relation to a particular chemical which will affect adsorption or retention.

So I don't think we can talk about standards per se. We are talking about defining the effects in the body associated with these things. We should be very careful in what we propose in terms of looking at the toxicants in relation to the amount of contaminants that are going to be in the water. We have got to understand at what level man can tolerate these things before we worry at all about the standards.

WORKSHOP ON HEALTH EFFECTS OF POTABLE REUSE ASSOCIATED WITH VIRUSES AND OTHER BIOLOGICAL POLLUTANTS

Chairman: Edwin H. Lennette, California Department of Health
Vice-Chairman: Gerald Berg, Methods Development & Quality Assurance Laboratory,
Environmental Protection Agency, NERC, Cincinnati, Ohio

PRIORITY 1 - ADSORPTION OF VIRUSES TO SOLIDS (High Priority)

Rationale

The disinfection process is a major means by which viruses are rendered non-infective in any water treatment system. In order to achieve disinfection, the inactivating agent must reach the virus. When viruses are imbedded in fecal or other solids, or physically protected by adsorption to clays or hydrated metal oxides, the chlorine or ozone or other disinfectant species will not reach the virus or may diffuse so slowly through the debris surrounding the virus that disinfection will not take place in the retention times available. This is a very real problem with renovated waters inasmuch as fecal material which escapes the earlier treatment processes will reach the disinfection process.

Methods are needed for the determination of the extent to which protection is afforded to viruses by adsorption to, or entrapment in, solids at low turbidity levels (0-1 JTU).

Research

The approach to this problem should consist of a two-stage program concerned with first, the development of methods for the detection of viruses on or in solids and the role that each of the various types of solids might play, and second, the development of methods by which the adsorbed viruses may be exposed to the disinfectant and thus inactivated.

The types of solids which should be examined include fecal matter, clays, hydrated metal oxides, carbonate and phosphate precipitates, activated carbon, activated sludge, and organic matter. This phase of the research program might require approximately three years.

Investigation of the methods by which the disinfection process might be improved should include at least the effect of increased contact time and disinfectant dosage, power input to provide disintegration of the solids, and disinfection by the methods which do not depend upon a diffusing molecule, e.g., ionizing radiation.

This latter study may require three years but could, in its latter stages, overlap with the study mentioned above. Length of Study: Five to six years.

PRIORITY 2 - METHODS FOR DETECTION OF HEPATITIS A AND OTHER VIRUSES IN WATER (High Priority)

Rationale

Hepatitis A virus is the major enteric virus involved in water-borne disease outbreaks, and the development of methods for its detection and identification are of the highest importance. The development of methods for detecting and identifying other viruses that occur in water and can infect man are also important.

Research

Methods are needed for the detection, isolation and assay of hepatitis A (infectious hepatitis) virus. Although current research indicates that this agent can be propagated in marmosets, *in vitro* methods are necessary if meaningful studies on the occurrence, persistence, and fate of the virus in wastewater as well as in various treatment processes is to be assessed.

Methods are also needed for the detection, isolation, and assay of other viruses excreted from the human enteric tract, and which are of public health importance in renovated waters. The viruses of major public health significance in renovated waters are obviously those which are capable of infecting or colonizing the intestinal tract, and which are excreted in large quantities. These agents belong to the following major viral groups:

- Hepatitis A viruses (ES)
- Hepatitis B virus
- Enteroviruses
  - Polioviruses
  - Echoviruses
  - Coxsackieviruses, Group A
  - Coxsackieviruses, Group B
- Adenoviruses
- Reoviruses

Other viruses that may be excreted by man in the feces, urine, saliva, and in respiratory, genito-urinary and ocular secretions may also be of potential public health significance in renovated waters, but they have not been isolated from domestic sewage or treated sewage effluent, and thus are of unknown significance.
Length of Study: Four years.

PRIORITY 3 - INACTIVATION OF VIRUSES IN RECLAIMED WATERS (High Priority)

Rationale

At the present time there is only very limited information on the mechanism(s) of inactivation of viruses by disinfection and adsorption. The necessity for obtaining exact information on this problem is based on the following considerations:

1. Our present knowledge of the mechanisms of viral inactivation is based primarily on the use of polioviruses as a model. However, with respect to reclaimed water, there are more than 100 other viruses which are of potential concern. Admittedly, it seems unlikely at the present time that all of these viruses will be studied in the near future from the standpoint of inactivation. However, if the exact mechanism of inactivation were known for some of the more typical or more frequently occurring viruses, then it might be possible to predict the approximate rates of inactivation of all, or perhaps many, of the other viruses.

2. Knowledge of the mechanisms of viral inactivation could quite conceivably lead to modifications of existing processes from the standpoint of increasing their efficienty in the inactivation process.

3. The fate of viruses in sludges may become predictable when adsorption mechanisms are better understood. The isolation and enumeration of viral particles in sludges is very difficult, but if the mechanism of the adsorption process were understood, present methods of viral quantitation could be evaluated and their usefulness enhanced.

Research

The research program to develop the mechanisms mentioned might be conducted roughly in the following order.

1. Methods and mechanisms of disinfection of viruses by chlorine and ozone.

2. Nature of the fundamental chemical reactions between viruses and disinfecting chemicals. There is need to develop the necessary methods for determining these reactions.

3. Determination of the factors which affect process control and which, when optimized, will assure an essentially microbial pathogen-free water. Such factors must be evaluated in a full-scale wastewater treatment facility which has been designed and

operated for the purpose of producing a pathogen-free water. Factors that should be studied include turbidity, pH, disinfectant and disinfectant concentration required, interfering nitrogen species, and methods for total control of the organics of the water prior to disinfection.

4. Studies are also needed on the interactions between viruses, disinfectants, and constituents in the water which interfere with the disinfection process.

5. The significance of bacteria which contain the R+ factor.

6. Adsorption processes, e.g., cell particles, hydrated metal oxides, activated sludge, activated carbon, etc. Length of Study: Five years.

PRIORITY 4 - RAPID MICROBIAL TEST METHODS (High Priority)

Rationale

There is an unquestioned need for the development of a rapid and, concomitantly, relatively simple test method that would indicate the presence of viruses and other pathogenic organisms in renovated waters. The availability of such test systems are highly important because back-up systems are required to provide multiple levels of safeguards for water quality. Simple, direct biological tests are necessary in addition to, and as a control on, the other operating control systems already in use, i.e., the physical and chemical tests and controls. Length of Study: Three to five years.

PRIORITY 5 - SENSITIVITY OF CELL CULTURE SYSTEMS FOR DETECTION OF VIRUSES: A COMPARATIVE METHODOLOGY STUDY (High Priority)

Rationale

There is a need for a comparative methods study and evaluation of various cell culture systems with respect to their ability to detect viruses which might potentially be present in reclaimed waters. The best system(s) should be standardized so that a uniform method would become available to all workers, and would also permit a comparison of laboratory findings between laboratories.

Recommended Research

In order of preference, the cell systems to be studied are:

1. Primary human embryonic kidney (HEK)
2. Primary monkey kidney (MK)
3. Selected stable cell lines

At present the plating efficiencies of a given virus in the hands of different investigators or laboratories which use the same cell lines (but from different animals or sources) give variable results with respect to recovery of viruses.

Research should be supported to provide standarization of cell systems that would afford a reproducible method for recovering a test seed of virus and for assaying infectivity titers.

It is suggested that the following aspects be studied:

1. Relative sensitivity of the test lines to the viruses under study.
2. Methods of obtaining more vigorous cell monolayers.
3. Age of the cell in relation to susceptibility to viruses.
4. Optimal formulas for culture fluids and for agar overlays for prolonged maintenance of the cells.
5. The influence of the volume of viral inoculum on viral titers.
6. "Enhancers" to incorporate in overlays in order to obtain maximum sensitivity.
7. Relative sensitivity for the detection of viruses under agar overlays and under liquid medium.

PRIORITY 6 - INTERACTIONS BETWEEN MICROBIAL PATHOGENS AND SOILS (High Priority)

Rationale

Information is required on the occurrence, survival and fate of viral and bacterial pathogens in all types of treatment plant sludges and on the interaction between pathogens in the sludges and soils of varying composition.

Studies on this subject are important because it has been demonstrated that most of the viruses entering a wastewater treatment plant terminate in the sludges, and it has been documented that these viruses are released and moved through some soils.

Research

1. Methods should be developed for the detection and quantitation of viruses and other microbial pathogens in sludges.
2. Studies should be undertaken on the ability of sludge and soil to form a complex and to release viruses under varying conditions.
3. The capacity of soils of various composition to hold viruses and the conditions for promoting viral adsorption and prevention of their elution needs study.
4. Determination is required of the time necessary for self-purification of soil-receiving sites and the frequency with which safe sludge-loading can be conducted.
5. Clues are needed on the effect of operating conditions of a land treatment system on the survival and fate of viruses and other microbial pathogens in soil.
6. Methods should be developed for the disinfection of viruses and other microbial pathogens in sludges. Length of Study: Five years.

PRIORITY 7 - REMOVAL OF PATHOGENS BY pH AND COAGULATION (High Priority)

Rationale

There is a need to prepare from the existing literature a state of the art document concerned with the removal and inactivation of microbial pathogens by pH extremes and by chemical coagulation processes. Such information is necessary for a rational approach to the development and standardization of optimum treatment conditions for the removal and inactivation of microbial pathogens. Length of Study: Nine to twelve months. (In large part because of low cost involved.) (This project may already be under way.)

PRIORITY 8 - MINIMAL INFECTIOUS DOSES OF VIRUS FOR MAN (Medium Priority)

Rationale

At the present time there is no definitive, unequivocal information as to the minimal infectious dose of virus infectious for man by the oral route. Such information is important as it would provide the basis for establishing viral standards for renovated waters, both with respect to the potential hazard and determination of the extent to which treatment is required for the various end uses of renovated waters.

Research Need

Information on the minimal amount of virus that will produce infection and/or disease in man by the oral route is almost non-existent or, at best, extremely limited, e.g., the work of Katz and Plotkin, using attenuated poliovirus. Considerable additional data beyond this are needed, and a research program employing human volunteers should yield the necessary information with respect to the minimal viral dose that would result in disease. The latter is a much more difficult factor to assess for a variety of reasons. One approach with respect to both infection and disease would be to determine the virus concentrations present in water during outbreaks of viral disease in the populations at risk. Length of Study: Five years.

PRIORITY 9 - TOXINS AND PYROGENS IN RECLAIMED WASTEWATER (Medium Priority)

Rationale

It is well known and recognized that during the processing of water which requires contact with such solids as activated carbon, microbes accumulate and consideration should be given to the release of toxins and pyrogens from such microbial agents.

Research

Information is highly desirable on the extent to which bacteria which colonize activated carbon and other solid contact systems release toxic and pyrogenic materials. A study should be undertaken to identify the toxins and pyrogens which may be released and their possible deleterious effects on the health of the population utilizing waters into which such microbial breakdown products are released. Length of Study: Two years.

PRIORITY 10 - SURVEILLANCE FOR VIRUSES IN EFFLUENTS FROM WATER RECLAMATION PLANTS (Medium Priority)

Rationale

At the present there is little, if any, information on what viruses may be present in effluents from existing pilot and full-scale wastewater reclamation plants.

Research

There is a need to conduct in-depth surveillance and monitoring for the presence of viruses, and their concentration, in effluents from existing pilot and full-scale wastewater reclamation plants which employ treatment trains that are likely to be used in future reclamation plants aimed at production of potable water.

It is only by having information available on the concentration of viruses (if any) present in reclaimed water that we can begin to consider rationally the public health significance of viruses in such waters. Length of Study: Three years.

PRIORITY 11 - AIRBORNE CONTAMINATION FROM WASTEWATER RENOVATION PLANTS (Low Priority)

Rationale

The potential public health hazard of airborne dissemination of pathogenic bacteria and viruses needs study because of the general lack of information on this subject, and because of the adverse public reaction to plant-siting engendered by misapprehensions on the possible hazards.

Research

Studies and research are needed on the following aspects:

1. Development and application of methods for the sampling, concentration, and detection of airborne pathogenic microorganisms.
2. Information on the factors that favor or adversely affect survival and dissemination of pathogenic microbes in the airborne state.
3. Development of methods for controlling the generation of aerosols and the aerial transport of pathogenic microorganisms.
4. The public health significance of airborne pathogens from treatment plants as determined by epidemiologic and other studies on the role of such airborne pathogens. Length of Study: Three years.

Workshop Participants:

Gerald Berg- Vice-Chairman, Methods Development & Quality Assurance Research Laboratory, NERC-EPA, Cincinnati, Ohio.

John T. Cookson - University of Maryland, Civil Engineering, College Park, Maryland.

Stuart D. Dunlop - University of Colorado Medical Center, Denver, Colorado.

Beatrice England - San Diego County Health Department, San Diego, California.

Edwin H. Lennette - Chairman, State of California, Biomedical Laboratories, Berkeley, California.

Leland J. McCabe - EPA, Criteria Development Branch, Water Supply Research Laboratory, Cincinnati, Ohio.

A. M. Aupen - N.I.W.R. C.S.I.R., Pretoria, South Africa.

Mark D. Sobsey - University of North Carolina, Chapel Hill, North Carolina.

Otis J. Sproul - University of Maine, Orono, Maine.

Craig Wallis - Baylor College of Medicine, Houston, Texas.

Comments on "Municipal Wastewater Reuse Proposed Strategy Document"

Otis J. Sproul
University of Maine
Orono, Maine 04473

The research needs for "Health Effects of Potable Reuse Associated with Virus and Other Biological Pollutants" will not be met by the program proposed in "Municipal Wastewater Reuse Proposed Strategy Document". The research program in the biological agent area would develop background data for various wastewater treatment trains. These data cannot be obtained from studies in large scale treatment facilities such as those normally funded in the AWTR program. To attempt to derive requisite data from studies in these facilities will not be cost effective. In most cases the information will be obtained from basic research studies.

These research needs will be met by a basic research program. The data from these studies will interface with the AWTR program to modify the design, operation and evaluation of treatment systems.

DISCUSSION

COMMENT: Mr. Parker, Brown & Caldwell, Walnut Creek, California. There are two items in your report which to me, seemed to be out of place in this context, that of municipal potable reuse of reclaimed water. Very high priority is given to determining the fate of viruses in sludge when applied to land. My feeling is that this is a general phenomenon and associated with all water pollution control projects and not directly related to the quality of the product of the potable reuse water. And I would not, in the context of water reuse, give this a high rating, although in the context of water pollution control and sludge disposal, I would. The point should be made that one alternative might be land disposal of sludges from the advance waste treatment plants that might produce reclaimed water, but that is only one of many possible alternatives.

Another point I would like to make before sitting down is in regard to one of those areas that is related to all sewage treatment plant operations, and that is the public health significance of airborne microbial contamination. This one, however, is given a low rating so I can't get excited about it, but it also is one that, in the overall context of water pollution control, is important. However, perhaps as far as diverting funds from potable water reuse to that area, I couldn't give it a priority. But I see that you haven't given it a high priority.

COMMENT: Mr. Lennette, State of California, Biomedical Laboratories, Berkeley, California. I see Dr. Berg can hardly wait to answer you.

RESPONSE: Mr. Berg, Methods Development & Quality Assurance Research Laboratory, NERC-EPA, Cincinnati, Ohio. I just want to be available to answer questions along with Dr. Lennette and that is the only reason I stood up.

But since I have been pointed to, let me simply say that I think you are absolutely correct. It is just a question of where you draw the line. If the virus in sludge is important in the renovation process, it's because you are dealing with the total process. If you want to say it is important also, and in a primary sense, in ordinary wastewater treatment, that's true. There's nothing untrue about that.

As far as the low priority given to the very last one, I have a suspicion that it was given a low priority by different people for different reasons. In my own case, it was given that primarily because I knew that the Army was already involved in extensive studies of that sort, not because I thought it was unimportant.

COMMENT: Mr. Cookson, University of Maryland, College Park, Maryland. With regard to the high priority on virus retention and movement in soils, I think indeed this does not impact directly with regard to direct potable water reuse. I think what we are trying to emphasize is that this is really something of importance right now, not only with regard to direct reuse, but because it has such significance in indirect seed spreading and also in the application in land treatment.

There is the possibility that aerosols may create a problem by impacting on direct water reuse. We are finding in some of our high quality treatment facilities, where we have to meet very, very stringent coliform standards on the effluent, that if we are not careful we get immediate recontamination from the air with coliforms after a post-aeration process or something of this nature. So, it may be important how you locate your final reservoir in relation to the treatment plant.

COMMENT: Mr. Sobsey, University of North Carolina, It occurred to me after yesterday afternoon's session that there were probably a number of research needs that we simply never got around to addressing. In fact, I thought one of them was so important--at least, I, personally, thought it was so important that I ought to mention it now.

I feel that there is a very strong need to conduct in-depth surveillance and monitoring studies for enteric viruses in effluents from existing pilot and full-scale wastewater reclamation plans employing treatment trains that are likely to be used in the future for potable water reclamation plants. This is needed in order to determine how much virus, if any, is present in such effluents. It is only by knowing how much or, perhaps, how little virus is present in such reclaimed waters that we can begin to rationally consider the public health significance of viruses in such waters. So, I think monitoring and surveillance are some things that we need to do right away, using the best available methodology that we have at hand.

RESPONSE: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. I believe that Frank Dryden and the rest of the other group on wastewater reuse would say that that kind of characterization was meant to be involved in the statement that he made about characterization on unit processes. We would agree with you one hundred percent.

COMMENT: Mr. Lennette, State of California, Biomedical Laboratories, Berkeley, California. Might I ask Dr. Sobsey to formulate a statement that we can incorporate into our document?

RESPONSE: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. We are perfectly willing to have him do that, but I reiterate it would be redundant to what is included in the proceedings so far.

RESPONSE: Mr. Cookson, University of Maryland, College Park, Maryland. In going over this with the committee, it was my impression that we had included what Mark just referred to. Perhaps it did not come out explicitly in the paper, but this was really under the disinfection heading as follows:

"Demonstration of factors that effect process control which, when met, will assure an essentially virus- and pathogen-free water. Such factors must be evaluated on full-scale wastewater treatment facilities designed and operated for the purpose of producing virus- and pathogen-free waters."

To do this, you really have to go through an elaborate monitoring process with regard to parameters. I think it is in here. Maybe it needs to be emphasized.

RESPONSE: Mr. Lennette, State of California, Biomedical Laboratories, Berkeley, California. This was the basis for my request to Sobsey. I want the record to show that we have considered it. This was not an error of omission.

RESPONSE: Mr. Parker, Brown & Caldwell, Walnut Creek, California. I think we have hit it more than once and I think we are beating it to death. Under research needs, in the treatment for potable reuse viruses are listed as a high priority item, and the following general statement is made: "All pollutant characteristics and the capability of the individual processes to remove them will help establish intelligent source control parameters as well as potentially lead to process improvement and new process development."

This is just one of the items that we want to see monitored through the potential treatment trains. Whether it is done in existing pilot plants or new ones really will depend on funding and the people involved in the program. I don't think that we need to enter into that. I think that we have covered that area very well.

COMMENT: Mr. Goldsmith, National Cancer Institute, NIH, Bethesda, Maryland. I may have misunderstood, or I may be naive, but it seems to me that if one is concerned about the viruses in wastewaters which are ultimately processed and used for human consumption, one would like to have long term monitoring of the harboring of virus disease among employees of wastewater treatment plants. This is necessary because the infectivity, and the trace of infective agents and strains, may indeed appear earlier among people who have an occupational exposure than among the people who are the clients or customers.

I think that you are going to hear much more frequently in other forums the premise that when you are talking about making a new product available to the consumer that the detailed occupational experience of the people who handle and use that product is going to be thought of as relevant. I believe that this epidemiologic monitoring system is necessary and that we have the tools to undertake it.

RESPONSE: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. It certainly is part of our program and we need to expand that.

COMMENT: Mr. Dryden, Sanitation District of Los Angeles County, Whittier, California. I would like to point out that there is some virus monitoring currently going on. In particular, we have embarked upon evaluating some specific trains for virus removal in Pomona, California. The State of California and the EPA are cooperating with us at this site. There are some reasons to look at virus removal for water reuses other than potable reuse, and a lot of these reuse applications are going to be developed.

I would also add that the characterization studies called for in our particular treatment group, however, were related to complete treatment chains which were deemed to be relevant to a potable reuse scheme. We feel that this, too, is going to have to be done when those trains are put together. But there is work going on now on monitoring of viruses and it must continue.

COMMENT: Mr. Shuval, Hebrew University, Jerusalem, Israel. I would like to relate to this problem of issues that are put into the recommendations of this workshop which really are universal in nature and do not refer directly or specifically to wastewater reuse either directly or indirectly.

I think many of the proposals, including the ones on epidemiological studies among workers and viruses in sludge, are subjects that have to be dealt with in any water pollution control program and they should not be included in this report as a special burden for wastewater reuse applications. I think that someplace in the preface of the study or in each section (and I don't think you should cross them out at this stage), some identification should be made of those points which are obviously going to be covered by other programs and should not be considered part of the multimillion-dollar package which is a prerequisite to get approval for wastewater reuse.

RESPONSE: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. That's a good point and I think we will take that into consideration.

COMMENT: Mr. Shuval, Hebrew University, Jerusalem, Israel. I think the report should be as specific as possible. What are the specific additional research missions required to further this specific program which are not being carried out?

RESPONSE: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. Oddly enough, we have an administrative problem along that same line. So, we are very sensitive to that. We have two Bills which both talk about reuse. We want to make sure that each one is applied to both pollution control and the health aspects of drinking water.

COMMENT: Mr. Shuval, Hebrew University Jerusalem, Israel. I would like to make one small comment on the question of rapid monitoring methods for viruses. I neglected to mention in my talk that I think there is some hope in this direction. Dr. Alcott Nelson of our staff of the Hebrew University has made considerable progress on a fluorescent antibody technique for detecting enteroviruses or polio viruses. A "Yes"-"No" qualitative answer can be obtained within nine hours and a quantitative answer within twenty-four hours. We think, with refinement, this can be improved. So we feel that the methodology for achieving this is on the horizon.

RESPONSE: Mr. Lennette, State of California, Biomedical Laboratories, Berkeley, California. We are striving for two hours.

RESPONSE: Mr. Shuval, Hebrew University, Jerusalem, Israel. I realize that. And I think there may be hope for bringing it down to five or six hours. I think you need one viral replication process to be able to identify something in the cells, and that's about four or five hours.

WORKSHOP ON HEALTH EFFECTS OF POTABLE REUSE ASSOCIATED WITH ORGANIC POLLUTANTS

Chairman: Hans Falk, National Institute of Environmental Health Science
Vice-Chairman: Robert G. Tardiff, Environmental Protection Agency, NERC, Cincinnati

Many existing water supplies contain detectable quantities of organic compounds. These organic compounds in water may represent a possible health hazard if they are carried through into potable water supplies. The sources of organic pollutants in water are diverse and include municipal wastewater, airborne wastes, industrial and agricultural wastes, and other products of commerce. For certain pollutants, studies should be undertaken to evaluate the relative hazard of these compounds from water in comparison with other sources.

1. Development of a Viable and Visible Program to Assess the Potability of Reused Water with a Program Manager and Coordinator.

Owing to the diversified problems involved in evaluating the health effects of potable reuse associated with organic pollutants, to include toxicity, hazard, analytical, and problem definition, it is recommended that a program or project manager or coordinator be established at EPA headquarters. The appointed individual should be charged to prepare a critical path or similar analysis and define time and dollar needs and constraints.

2. Determine the Definition of "Potable" Scientifically and Operationally.

The information required to assess potability of water generated directly from sewage is included in the information required to assess the potability of water derived from polluted water sources.

There is a requirement for a scientific definition of what constitutes "potable quality". When this has been accomplished, the development of requirements for toxicity, hazard, and analytical chemistry research will be clarified. Safety factor development will be a politico-economic decision based upon acceptable risk. There is a need for the development of screening methods and the application of existing methods which are reliable, inexpensive, and rapid. Short-term (hazard analysis) should be applied to "grab", "natural" samples. Long-term studies should not be applied to these types of samples without developing a means of characterizing natural samples. There is a need for such characterization. This characterization should not be confused with complete chemical analyses. Long-term studies should be designed so that the results are applicable to a series of problems and, therefore, should best be performed on well defined samples. Cost/benefit should be a consideration in the development of long-term studies.

As objectionable organoleptic properties of reclaimed water will be prohibitive for its use and because the human nose acts as a potential warning system for the presence of organics in the water because many organic pollutants can be smelled before their concentrations in the water become acutely toxic for human beings, the reclaimed water as well as individual pollutants should be screened for organoleptic properties. More threshold odor (taste) concentration data for organics should be obtained and criteria for restriction of their discharge in the sewage system should be developed.

3. Development of Sensitive Analytical Methodology for Organics in Water

The EPA must support research programs designed to identify specific organic water pollutants, some of which may be hazardous to health. Techniques of isolation, concentration, identification, and quantitation of organics should be improved. Techniques must be developed that allow quantitative recovery of compounds without introduction of artifacts. More work needs to be done on the identification of non-volatile, higher molecular weight compounds. Research in analytical methodology for organics in water should be coordinated with ongoing work in program areas of sewage, industrial wastes, and drinking water analysis.

4. The Investigation of the Toxicity of the Byproducts of Various Types of Disinfection (e.g., chlorination, ozonation, UV light, etc.)

The effects of deterioration of water for biological safety has brought with it the creation of many new and potentially toxic chemicals. Attention must be paid to the reaction products which may be just as toxic or even more so than the products of deterioration. The instability of some of the products may be of some help, but the residual compounds, epoxides, aldehydes and acids may need careful assessment.

Water samples must be analyzed for chemical composition before and after the chlorination treatment step, because certain organic components, like the phenols will give rise to chlorinated phenols with much greater toxicity.

5. Development and Application of *In Vitro* Microbiological Assays for the Screening of Organic Mixtures in Reused Water

The recent development of *in vitro* bacterial systems which serve as sensitive indicators of a candidate compound's carcinogenic/mutagenic potential should be given serious consideration as a screening tool early in the hazard evaluation of a compound or water concentrate-residue. Since various test systems are being studied intensively, and others are evolving, the EPA should remain alert to new developments in order to apply the most useful and reliable methods. The introduction of hepatic microsoma fractions of rodents or humans helps to allow for metabolism of the compound as would occur in mammalian species.

Besides these tests for mutagenicity, which also serve as alerting systems for carcinogenicity testing, other *in vitro* test systems assess cytotoxicity, chromosomal abnormalities and toxic effects to hepatic cells in culture, to name only a few *in vitro* tests involving mammalian cells.

6. Toxicity Testing of Water Samples of Fractions of Concentrates

At some stage, there will be a need to carry out short-term toxicological studies on actual wastewater effluents (and concentrates of them) produced by advanced waste treatment facilities designed to produce water for potable use. A pre-requisite for carrying out such studies is the development of appropriate techniques for concentrating refractory organics present in the waste stream which would, to the extent feasible, maintain the integrity of the chemical components, avoid change of the relative concentrations, and do not lead to the loss of essential fractions. A standard protocol for such tests should be prepared to assure the reliability and comparability of such studies.

The significance of the results from tests using mixtures (i.e., concentrates) is to predict relative toxicity, prioritize the in-depth analysis of samples and systems, and suggest leads of target-organ toxicity. Only chemicals identified from highly toxic fractions and suspected of being chronically toxic would be subjected to longer-term and highly specialized toxicologic testing including the investigation of their synergistic potential.

Long-term feeding studies with animals may be necessary in the overall evaluation of the potential hazards of renovated wastewaters. Such investigations must use discrete entities which have been identified in the water systems of interest. The use of water concentrates for this type of study would have only limited value in relation to the broad problem. We know that natural materials vary in composition and amount over time. Thus a concentrate would be representative of the water supply only for the time when the sample was collected. Also if adverse effects are observed, the causative agent(s) could not be determined. In addition, the volume of a representative water sample required for an animal study of any significance would require massive volumes of water--not taking into account the losses of volatile components during concentration.

7. The Metabolism of the Organics in the Reused Water Should Be Studied in Order to Determine the Best Possible Models for Toxicity Testing

In attempting to identify the hazards of compounds in potential drinking waters, the metabolism in mammalian systems of suspect compounds should be studied. Utilization of short-term *in vitro* procedures, such as use of animal or human liver tissue, may provide important guidelines in the early screening evaluation of compounds of interest.

8. Assessment of Interaction of Pollutants

Of particular importance are synergistic effects of, for instance, specific chlorinated hydrocarbons with alcohols and their oxidation products (aldehydes and ketones) in enhancing this toxicity. Synergism is also at play when enzyme induction may enhance the toxicity of compounds as CCl_4. Synergism has also been demonstrated for odor enhancement making such contaminated water undesirable.

9. Development of Rapid and Reliable Methods for the Monitoring of AWT Effluent and Their Correlation with Toxicity

Development of gross chemical or biological methods which give good correlation with presence of compounds of health significance are needed which can be used for routine monitoring of drinking water supplies to give reasonable assurance that organics in the water do not constitute a hazard to health.

Organic materials enter water supplies from municipal, agricultural, and industrial wastes, and from natural sources. Others are formed during water or wastewater treatment. Some portion of these organics are potentially hazardous to public health and may reach the consumer even after treatment. Relatively simple and rapid analytical procedures are required for routine use to detect when the concentration of organics reaches levels which are of questionable safety for human consumption and thus require more critical analysis and consideration. Analyses such as COD, TOC, CCE, VOA, pH, mutagenic microbial assay, and other potential gross analyses should be compared with measured concentrations of compounds found in water and known or determined to be potentially hazardous so that safe levels, based on the gross techniques, can be established.

10. Monitoring of Renovated Wastewaters and Water Supplies Is Needed to Determine What Organic Compounds Are Present, Their Concentrations, and Their Variation with Time.

In order to evaluate the potential health hazards of reclaimed waters for potable reuse, there is a primary need to establish the kinds of organics which are present and their concentrations. Such background information will aid in the formulation of toxicological and other health hazard assessment plans for organics in drinking water. In addition, it will be most useful in comparing characteristics of organics in reclaimed wastewaters with present drinking water supplies. This information will also be most useful in evaluating the need for and value of various unit processes which may be used for wastewater renovation.

11. Thought Should Be Given to Epidemiologic Studies, Where Applicable, on the Correlation of Human Disease and Exposure to Organic Compounds that Occur in Drinking Water and Other Media

It is recommended that EPA consider participation in the WHO International Reference Center on Community Water Supply's proposed study to determine the feasibility of carrying out retrospective and prospective epidemiologic surveys on population groups exposed to heavily polluted surface waters (indirect or covert wastewater reuse). The aim is to determine whether there are any detrimental health effects resulting from such long-term exposure. Such studies might include testing of the body fluids and tissues for the accumulation of compounds of potential toxicologic importance. Consideration should be given to carrying out such carefully designed studies in a number of countries on an international cooperative basis.

An assessment of body stores of some of the organic components of reused water in human tissue should be carried out. This will deal mainly with stable, lipid soluble compounds which will reach man also through the food chain and by other means (medicines for instance). $CHCl_3$, CCl_4, trichloroethylene and perchloroethylene have already been detected in samples of adipose and other tissue of humans. This information is of importance in assessing potential hazards of certain organic compounds even if present in minute amounts in drinking water.

12. Assessment of Occupational Hazards to Operators of Wastewater Renovation Facilities.

Besides the hazards of exposure of workmen to chemicals related to the chlorination process, hazards of exposure to ozone or U.V. light should be considered in case these alternate routes are to be initiated.

13. Development of Channels of Communications and the Rapid Dissemination of Data.

Recommendations for Exchange of Information on Organic Pollutants in Water

(1) A brief international newsletter should be published periodically (bimonthly) containing submitted summaries of research being conducted or planned in the areas of identification, fate, and effects of organic pollutants in water or wastewater. Submissions should be solicited from all researchers in the area by appropriate advertisement. The purpose should be rapid dissemination of research results or intention before open literature publication.

(2) A second international newsletter, to be published quarterly, maybe even briefer than the first, should be designed for the tabulation of specific organic compounds identified in any water or wastewater, listing sources of the pollutant, concentrations, method of analysis, degree of confirmation, and very concise toxicity and organoleptic data. The first newsletter of this type should include copies of all existing lists of pollutants; e.g., the Project 646 list, the WHO water reuse conference (1975) list, the various EPA lists, etc. Information in these newsletters should be combined in about a year into a computerized master list of pollutants in water. If new compounds are identified by mass spectrometry, the spectrum should be submitted and forwarded to the EPA for inclusion in the NIH-EPA mass spectral search file.

14. Development of International Cooperation and Coordination.

It is recommended that efforts in the direction of evaluating the health effects of organics in water for direct or indirect wastewater reuse for potable purposes be coordinated on an international basis with such agencies as the International Reference Center on Community

Water Supplies of WHO, the European community, and specific countries directly involved in such endeavors. To the extent possible, test procedures for identifying organics should be standardized so that comparable results can be obtained on water sources from various parts of the world. Sampling methods, techniques for concentration, toxicological screening methods, and long-term toxicological testing programs should also be standardized and coordinated internationally. The output from the various international programs should be integrated and disseminated on a regular basis to all participants of the program.

Workshop Participants:

Gary F. Carlson - University of Rhode Island, Kingston, Rhode Island.

Robert B. Dean - AWTRL, US-EPA, Cincinnati, Ohio.

Hans L. Falk - Chairman, NIEHS, Research Triangle Park, North Carolina.

A. W. Garrison - EPA, Athens, Georgia.

Cheng-Chun Lee - Midwest Research Institute, Kansas City, Missouri.

Perry McCarty - Stanford University, Stanford, California.

Gordon W. Newell - Stanford Research Institute, Menlo Park, California.

Raymond E. Shapiro, Epid. Unit, DHEW-PHS, Washington, D.C.

Hillel I. Shuval - Hebrew University, Jerusalem, Israel.

Marshall Steinberg - U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland.

Robert G. Tardiff - Vice-Chairman, EPA, NERC, Cincinnati, Ohio.

B. Cees J. Zoeteman - WHO International, The Hague, The Netherlands.

DISCUSSION

COMMENT: Mr. Jack Glennon, U.S. Army Medical Research Development Command, Washington, D.C. I just want to make a comment here on a potential problem. You've got a pretty good out in your last paragraph here: "To the extent possible, test procedures for identifying organics should be standardized." I am assuming you are talking about international standardization here. When I was in Paris last fall, various people from EPA presented their GCMS capabilities, and the people from Europe just stood there in awe. They just don't have this type of capability and they don't have the resources to get into this. So, I think the discrepancy between the quality of the data from international studies and the quality of the output from international studies could be a severe limitation.

RESPONSE: Mr. Falk, NIEHS, Research Triangle Park, North Carolina. We have a gentleman from Holland here who might be able to give some comment on that. Could you?

COMMENT: Mr. Zoeteman, WHO International, The Hague, The Netherlands. I certainly was not at this meeting. Currently, I think quite an effort is going on in Europe to identify organics in waters. The Commission of the European Community started only recently to coordinate this work, and they identified quite a number of compounds. Certainly, we agree that you here in the United States started in this field some years before we did. But I think that cooperation in the future would certainly be of mutual benefit.

COMMENT: Mr. Dean, AWTRL, US-EPA, Cincinnati, Ohio. I would like to respond to Jack Glennon. I agree that we have more mass spectrometers in this country, but the better labs in both countries are comparable. Werner Stumm was telling me of his capabilities. He has opened up a complete "quantum jump," as he said, in the ability to analyze compounds. There are very capable laboratories in Europe and we shouldn't run them down.

COMMENT: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. I don't think that was Jack's intent.

RESPONSE: Mr. Glennon, U.S. Army Medical Research Development Command, Washington, D.C. No. Just let me clear my conscience here. The main point I wanted to make is that the financial resources to invest in these types of facilities, especially when the state of the art is advancing so fast that by the time you get your mass spectrometer in it has passed you by, can be a real problem.

COMMENT: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. I would like to emphasize that we want to get quantitative data wherever possible. We have been looking at this well-identified list for a long time, but it hasn't been too satisfactory.

COMMENT: Mr. Goldsmith, National Cancer Institute, NIH, Bethesda, Maryland. I am enthusiastic about getting good analytic work on both organic and inorganic materials in water supplies, and I know that this is a prerequisite to adequate health effects studies. But I am troubled about the necessity of including the consideration of analytic procedures in panels on health effects. I suspect, and I am anxious about the possibility that this may reflect a program decision which, if it were being made, would be made erroneously. I think it is extremely important to establish analytical procedures and determine what materials are present in water systems because of the necessity for evaluating the health responsibilities. Possibly we should even consider rewriting the organization of the material which has been considered to include a section on analytical procedures. However, I am reluctant to see this included as part of the health effects program in program budgeting and management. I think if we are not careful we will use up all the resources which have always been scant for health effects studies, for the great satisfaction of improving sensitivity, validity, reliability, and identification of some new agent which may be very important for health purposes. I think that this is a separate program responsibility, and I am warning my colleagues that if this is not isolated and kept within a separate budgetary and administrative category, we are going to find ourselves without support for health effects research.

RESPONSE: Mr. Falk, NIEHS, Research Triangle Park, North Carolina. In our discussions throughout the days, we were always basing our biologic test procedures and the need for various tests on the basis of having identified components in whatever we tested. We held a long discussion on the need to test fractions that were subfractions of actual concentrates, and had a great deal of difficulty because of some of the changes, losses and alterations that would occur. Therefore, many of our tests would be carried out on compounds that are pure and that have been identified as components.

COMMENT: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. We are very conscious of this, Dr. Goldsmith, and our approach to it is to put the health effects people in charge of the overall mission so that they can control the matter of how much goes into analytical development to suit their programs. In that way, you don't have an "ivory tower" of refinement perhaps beyond their needs. I hope that this approach works.

COMMENT: Mr. Marshall Steinberg, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland. I accept what Dr. Goldsmith says, but I think we should take a lesson from standards established in the past, and not necessarily water standards, where a standard was established on the basis of the analytical technique that was available. This is not to say that it was tied to the fact that we could measure it, but that the number has a direct bearing on your ability to reproduce your data. And to generate a lot of human data which requires the analytical support of one method and then, a short time later, apply a new analytical technique to the measuring may either produce a situation in which your constraints are too tight or, in fact, not tight enough. I think the industrial hygiene field is living with this problem today.

COMMENT: Mr. Christian, University of Cincinnati, Cincinnati, Ohio. I was very pleased to see the inclusion of your work on *in vitro* systems. One thing that rather concerns me is that they are usually talked about as screening systems. I think that they can be most useful when integrated with the total toxicological input and not used merely to look for a specific fact. I think perhaps some of the systems have limited usefulness if they are not integrated with animal systems.

COMMENT: Mr. Middleton, NERC, US-EPA, Cincinnati, Ohio. I would just like to make the comment that we have to keep very much in mind, with all of this analytical talk, the quality assurance and validity of our own data. It is very hard, as we have all found out just in one country, to have assurance that the data are comparable from one laboratory to another. It is triply difficult if we do it on an international basis. However, there is a tremendousnecessity for us to be sure that our analytical data are valid and that they have quality assurance built into them. Otherwise, we have a lot of things that we can't compare.

WORKSHOP ON SOCIO-ECONOMIC ASPECTS OF POTABLE REUSE

Chairman: E. G. Altouney, National Oceanic Atmospheric Administration
Vice-Chairman: Richard K. Schaefer, EPA, Washington Environmental Research Center

INTRODUCTION

It was the consensus of the group that in general, the research needs for Socio-Economic Aspects of Potable Reuse are of a lesser priority than the health aspects.

In considering the socio-economic aspects of potable reuse it should be pointed out that much of the water supplies currently furnished contain significant amounts of wastewater from upstream communities. This indirect reclamation and reuse should be recognized in that quality standards for water supplies and wastewater reuse for potable purposes should be the same.

In addition there are many areas of reuse other than potable that should be recognized as important extenders of the community water supplies. These other reuse aspects still present problems relating to acceptability. For example, use of treated wastewater for agricultural purposes presents concerns to agriculturists over crop yield reduction as a result of build-up of salinity levels and critical trace elements over long periods of time. Such concerns are also valid when irrigation water ultimately infiltrates into a groundwater basin which serves other uses. Even though the group identified health aspects of wastewater reuse as paramount in importance, the following projects were identified as meriting investigation by descending order of priority.

1. National Survey and Local Investigation of Areas of Water Recycling Feasibility (High Priority)

A. SPECIFIC RESEARCH NEEDS

1. To identify the extent to which the U.S. population is presently being supplied former wastewater as part of their raw water supply.
2. To select up to 10 (ten) U.S. locations of varying characteristics and conduct an in-depth investigation of potential reuse cost-effectiveness.

B. DISCUSSION

1. Reason for Specific Research Needs
   a. In most areas of the United States, water utilities are dealing with an ever-increasing degraded water supply of which the health aspect studies relating to this practice have not been faced or the relationship to this aspect of water use and its correlation with direct and indirect reuse set forth.
   b. It is recognized that local factors such as size, industrialization, climate, etc., have a significant effect upon the economics, or cost-effectiveness, of reuse. It is considered impossible to provide meaningful answers to the economic uncertainties

on a national scale, however, if typical "types" of different areas were properly selected, then case studies of cost-effectiveness would be important.

2. Suggested Approach to the Problem

We would like to see EPA design a study and carry it out in general accordance with the following approach:

a. Number of cities using sewage water in their raw water supply.

b. Estimate the population drinking water composed of sewage water.

c. Develop a curve showing (a) and (b) above for the last 20 years and the next 25 years.

d. Quantify the percent of sewage in our nation's raw water supply in the years 1950–2025.

e. Estimate the percent of direct and indirect potable reuse over the next 50 years ±.

f. Identify those regions, areas, and communities of the nation which will soonest require serious consideration of reuse to supplement existing water resources. It is believed that this task could be accomplished by analysis of a variety of existing national survey data, supplemented by a limited additional amount of new developmental effort.

g. A number of these locations should be selected for in-depth investigation of reuse potential. Selection criteria should ensure that important variations (from a reuse economics and cost-effectiveness point are considered. Such criteria might include:

(1) Size, population, and other demographic variations. It is recognized that economics, for example, vary significantly between areas of different size.

(2) Degree of industrialization (with emphasis upon high water consumption industry) and irrigation demand (agriculture, golf courses, pasture, and other major irrigation water users). Also, extent to which land use controls have concentrated industrial, agricultural, residential users in specific areas. What is being sought in this criterion is to differentiate between an area where separate distribution is feasible, e.g., Odessa, Texas, from large metropolitan areas where separate distribution is not feasible, e.g., Denver, Colorado.

(3) Options available with regard to indirect reuse if any, e.g., is geology amenable to ground water recharge, is there a large storage

lake for storage and dilution, or is direct reuse the only feasible option?

    (4) Geographical location

    (5) Climatological differences.

b. The in-depth investigations in each of the selected locations should include at least the following:

    (1) At what points in time and water demand will the use of wastewater become economic, or cost-effective for each of the types of reuse including potable. In other words, develop an economic hierarchy of successive types of reuse.

    (2) To accomplish this, a series of supply-demand curves related to time is required. These curves are based upon population, consumption, etc. projections.

    (3) An evaluation of the water supply, wastewater disposal, water reuse situations present and future from a total systems perspective.

    (4) Legal ramifications.

3. Suggested Length of the Study is One Year, with 3-4 Man-Years of Effort.

2. Public Education on Current Indirect Water Recycling

Determine how the public, most of whom currently are using some reclaimed water in their domestic supply, can be informed of this in such a way that they will understand and accept it.

Reason for Specific Research Need

In discussions on direct reuse and what is needed to practice it safely, the fact that many so-called "virgin" water sources have for years contained significant quantities of wastewater has all but been ignored. Even direct reuse will involve some dilution within the distribution system. Therefore, in reality, so-called direct reuse would not introduce a completely new product. Thus, if the people already receiving a significant amount of reclaimed water in their potable supply could be shown and convinced that it posed no significant use problem, it would be relatively easy to show them that an increased amount of reclaimed water, after treatment to assure its quality, meets established goals.

Suggested Approach to the Problem

Conduct educational programs describing a number of cities that have for many years used source water containing varying percentages of wastewater. Determine whether or not there have been major health effects and a high number of customer complaints. The cities included in the study would have to be those producing a water of relatively high quality.

If the results of the study were favorable, the fact that the community had been using reclaimed water for years without adverse effects should be given to the people (in different ways in different cities) to determine their reaction. The most satisfactory approaches could then be used in communities finding it necessary to increase the percentage of reclaimed water directly or indirectly. Length: Undetermined.

3. Analysis of Legal Considerations of Water Rights Affecting Reuse (Medium Priority)

Recycling of municipal wastewater has the potential of impacting the quantities available for upstream and downstream water users. Individual state water laws will be interpreted, modified, or both, to accommodate the implementation of treated municipal wastewater reuse.

Identification of significant legal precedents which could constrain the implementation of such reuse is needed. This should be approached on a state-by-state basis in that water laws vary from state to state.

The respective legal aspects could change the present type of water use so that users requiring higher quality supplies could receive them, rather than having to resort to reuse. In addition, the level of treatment could be vastly different if such exchanges of water could be effected.

Analysis of the impact of such reordering of water uses could lead to identification of potential changes in existing water law. Length: Three person-months. (Note: Denver Research Institute is doing some of this.)

4. Analysis of Legal Considerations of Liability for Distribution of Recycled Water (Medium Priority)

Identification of sphere of impact when treated municipal wastewater is being considered for potable uses is needed.

Numerous regulatory entities exist that may have jurisdiction over various water-consuming activities within a given area. Identification of such agencies and delineation of their respective responsibilities and pertinent legislation, initially at the federal level, would provide water purveyors with an array of information which could assist them in becoming alerted to standards, regulations, and legislation that could constrain the potable reuse of treated municipal wastewater.

This is necessary in that the impact of potable reuse will not only be limited to direct human consumption, but also to industries such as food and beverage processers.

The environmental assessment could lead to considerable litigation if the appropriate standards, regulations, and legislation are not adequately addressed. Length: One person-year.

5. Analysis of Value of Water Quality to Consumers (Medium Priority)

Statement of Need

Basic economic data are needed on the value of a certain level of water quality to the consumer. That is, how much money is the average household consumer willing to pay for a higher level of water quality?

Discussion

Most municipal water treatment investment decisions are made by professionals based on their beliefs as to the value of a certain water quality level, or are made indirectly by consumers who vote on bond issues for new treatment facilities. The planning process would be significantly advanced if data were available on the perceived value of a higher quality water over another quality. This is particularly germane to decisions to implement recycling now, or to wait until technology is farther advanced, or to develop more expensive conventional supplies.

One suggested approach would be to measure consumer behavior directly related to water quality: (a) purchasing of bottled water by consumers as a function of income or sociodemographic characteristics; (b) purchases of home water-softening equipment; (c) comparative value of homes which differ only in quality of water service, if such can be found.

A study of (a) could be done in 5-6 person-months, from supermarket data on bottled water sales, related to census tracts, in a single water system. A study of (b) could be done by survey and would require 10-12 person-months.

6. Incentives to Cooperation Between Water Supply and Wastewater Agencies (Medium Priority)

Statement of Need

Conduct a study of the methods and effects of various methods of encouragement that can be exerted by funding and regulatory agencies on separate water supply and wastewater treatment entities to get them to coordinate their efforts in water management programs that include reuse.

Discussion

In many areas the water supply and wastewater treatment entities are separate units. This has resulted in some problems of cooperation and coordination in developing water management programs that include reuse. More specifically the problems included jurisdiction (which agency should be the lead one) and economics (who was to pay what portion of allocated costs). In the case of apparent lack of cooperation and coordination, encouragement from funding and regulatory agencies can be potentially effective in bringing about effective water management programs. The various methods of encouragement and the results of these methods should be investigated.

This study could be conducted within about one year, using 2.5 man-years.

7. Determine Acceptable Proportion of Recycled Water (Medium Priority)

Statement of Research Need

Determine, under varying sets of circumstances, the proportion of reclaimed water the public will accept in their domestic water supply.

Discussion

Through the different communities of the nation many different circumstances exist, and what may be appropriate for one area would be inappropriate for another. It would be helpful to have guidelines established which a local community could apply to its situation to determine its optimum alternate in developing a reclaimed water program. Such guidelines should provide both engineering and customer attitude data which would enable the comparison of items such as costs of higher treatment of wastewater vs. delivery of a safe but lower quality of water; increased use of reclaimed water vs. water conservation; increased use of reclaimed water vs. development of alternative "natural" supplies (icebergs, interbasin transfers, de-salting of ocean water, etc.). Length of Study: One year, using 1.5 person-years.

8. Problems Faced by Cities Pioneering Reuse (Medium Priority)

Statement of Need

Determine and forecast relative importance of types of sociological, institutional, and economic problems that will be faced by cities pioneering potable wastewater reuse.

Discussion

There is considerable evidence that public attitudes, based on deep-seated cultural taboos, oppose drinking recycled wastewater. This attitude persists despite objective evidence that "accidental" or indirect reuse, equal in contamination to direct reuse, is common. Further, the attitude is likely to persist to some degree even though scientific proof establishes that recycled water is equal to or superior to "fresh" water.

The problem faced by a pioneering city is that of public attention leading to scorn, for violating this taboo. Even though residents of the city may accept reuse, there is the possibility that other persons who have a free choice--e.g., tourists, convention-goers, persons who can choose between food and beverage products produced in the pioneer city or elsewhere--may irrationally treat the pioneer city as outcast. What action would successfully overcome these problems, e.g., educational campaigns?

The suggested approach would be to develop case studies from other cities which pioneered violation of cultural taboos to determine the reaction, and specifically to study public attitudes toward cities where a health problem--

real or imagined--existed to determine behavior patterns. Has there been any evidence of a reduction of tourist business or a boycott of products? After case studies are written, an interpretive analysis can be made, based on similarities in behavior, etc. Length: A 6-8 month study seems adequate; perhaps 15-18 person-months.

9. Socio-Economic Impact of Delay of Water Recycling (Medium Priority)

Statement of Need

Develop an assessment of the social and economic impacts on a municipality in case scheduled implementation of potable reuse is unexpectedly delayed and the implementation of contingency plans becomes necessary.

Discussion

A number of cities are proceeding to develop water recycling technology on the assumption that recycling for potable use will become feasible in another 15 years or so. The problem which could arise, however, is that public health hazards may not, after all, be overcome when scheduled. The possibility exists that a legal injunction may be granted, on the request of health experts or even environmental groups, which bars operation of the recycling plant.

If the city has abandoned development of conventional supply sources in anticipation of successful reuse, it cannot reverse strategy and develop these sources for some time. Instead the city would probably face forced conservation, the construction of dual systems for non-potable distribution, and a crash program of development of conventional water supply sources.

The suggested approach would be to select several cities for analysis, and simulate the impact of this disruption by assuming a certain percentage drop in water supply. The social and economic costs of the resulting impact can be estimated in terms of a forced reduction in consumption, and engineering estimates of the cost of developing a dual distribution system and/or replacement supplies can be projected. Each such impact can be stated in terms of present value. The cost of the forced reduction in consumption can be simulated by using estimates of price elasticity for water; i.e., how high a price increase would reduce household consumption by the same amount as the forced reduction. Length: The study would involve about 4 person-months plus 3 person-months for each city analyzed.

10. Study of Diffusion of Water Recycling to Other Cities (Low Priority)

Statement of Need

Determine the likelihood and extent to which sociological, institutional and economic problems faced by cities practicing potable use of wastewater will diminish, as more and more cities adopt this practice.

Discussion

There does not appear to be any diversity of expectation here. Observation and perhaps history shows that as innovations increasingly become adopted, resistance to adoption eases.

This is rather well documented by the literature on technology transfer, e.g., Havelock's work at Michigan and the pioneering work of Everett M. Rogers, in Diffusion of Innovations, dealing with hybrid seed corn, medical detailing, etc.

The suggested approach would be to apply innovation diffusion experience to matters akin to water recycling to see if the historic lessons are applicable. Examples of analogous situations should be given. Length: A 4-6 month study (some 7-8 person-months) seems adequate for a start--perhaps to completely research the subject.

Workshop Participants:

George W. Adrian - Los Angeles Department of Water & Power, Los Angeles, California.

Edward G. Altouney - Chairman, Marine Eco-Systems, NOAA, Boulder, Colorado.

Lloyd C. Fowler - Santa Clara Valley Water District, San Jose, California.

Stephen Heare - Arlington, Virginia.

Kenneth J. Miller - Denver Water Department, Denver, Colorado.

J. Gordon Milliken - Denver Research Institute, University of Denver, Denver, Colorado.

Richard K. Schaefer - Vice-Chairman, EPA, Washington Environmental Research Center, Washington, D.C.

Curtis J. Schmidt - SCS Engineers, Long Beach, California.

William Seeger - Kennedy Engineering, Inc., San Francisco, California.

Elroy F. Spitzer - AWWA Research Foundation, Denver, Colorado.

Roger A. Wiedelman - Bureau of Reclamation, Denver, Colorado.

Rocky Wiley - Denver Water Department, Denver, Colorado.

APPENDIX

In addition, the group recognized that it would be highly desirable for EPA to undertake a study dealing with the development of a viable and operable water conservation program for use by utilities.

Discussion

The general public over the years has been led to believe that there was an unlimited supply of water available. Recent experiences coupled with present and future population growth indicated that in order to provide adequate supply we cannot depend on the "unlimited supply syndrome" of the past. Due to the "unlimited supply" attitude that has existed the American public has unconsciously become very wasteful of water. A possible supplemental supply can, with adequate future research, be provided by wastewater reuse but at a relatively high cost. In view of the fact that our present supplies are more economical it is imperative from an economic standpoint that existing supplies be conserved to the greatest extent possible within the present "life style" of the community. In the past many agencies have developed "Water Conservation Programs" that can be useful and helpful to agencies being threatened by water shortages.

We feel that a Survey program directed to a review and compilation of the various programs in order to bring all information into one central location will provide great benefit to the American public.

In order to fully implement a successful water conservation program it would be desirable to conduct an "Attitudinal Survey" to evaluate consumer acceptance of a Water Conservation Program in a particular area. Such a survey would require the following two-stage approach:

1. Develop an evaluation of the impact of a broad water conservation program which reduces demand load and reduced patterns of usage of potable water supplied to buildings/occupants/residents.
2. Conduct an assessment of acceptance and implementation of innovative water system appliance and fixtures in dwellings and commercial buildings (e.g., dwelling storage of water from baths, showers, dishwashers and washing machines for flushing toilets) which alters flow into and from wastewater treatment plants.

DISCUSSION

COMMENT: Mr. Schmidt, SCS Engineers, Long Beach, California. I just wanted to comment that with respect to research project No. 5, which is "Analysis of Value of Water Quality to Consumers," I don't believe that the group intended that we think of water value only in terms of the household consumer. We were interested in water value to all types of consumers.

RESPONSE: Mr. Altouney, Marine Eco Systems, NOAA,Boulder, Colorado. That's an extension. I think it was indicated earlier in the presentation that we felt that not only potable reuse was deserving of additional research but also extended uses of recycled wastewater. We identified agriculture and, of course, there are other areas, too.

COMMENT: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. I suppose you would mean even in a city context, wouldn't you, Mr. Schmidt? Industrial use, for instance.

RESPONSE: Mr. Schmidt, SCS Engineers, Long Beach, California. Yes. That's what I had in mind.

COMMENT: Mr. Dryden, Sanitation District of Los Angeles County, Whittier, California. You commented on the agricultural use and expressed concern about factors such as the TDS of the water causing problems in the soil. Although that is true,it doesn't seem to me that that is uniquely related to recycled water. Natural water supplies with high TDS have the same problem. These are pretty well understood by people in agricultural fields, and you can determine before you use the water what kind of problems you are going to have, and whether it is suitable for soils you are applying it to, the crops you are applying it to, and so forth. I think that it is a general problem, and certainly not unique to water reuse.

RESPONSE: Mr. Altouney, Marine Eco Systems, NOAA, Boulder, Colorado. That's a well-taken point.

COMMENT: Mr. Dean, AWTRL, US-EPA, Cincinnati, Ohio. With respect to your point number 3, related to the legal considerations and the fact that you might be able to change the water laws, I would like to refer to a bit of history. Back in 1930, we had an advanced waste treatment program going on in Los Angeles with reused water--which was reported by Goudy. The purpose, according to Goudy, was to show that you could treat wastewater and make it usable again, and he succeeded. The real purpose was to get the people of Los Angeles so mad that they would vote the bond issue to bring in Colorado River water.

Is there a danger that the development in Denver is merely to change the water laws in the State of Colorado so that Denver, which has a large population, will get more of the water, and the agricultural land barons won't get the water they think they own.

RESPONSE: Mr. Altouney, Marine Eco Systems, NOAA, Boulder, Colorado. Perhaps I should refer the answer to this question to Ken Miller.

COMMENT: Mr. Spitzer, AWWA Research Foundation, Denver, Colorado. He has gone.

RESPONSE: Mr. Altouney, Marine Eco Systems, NOAA, Boulder, Colorado. I might answer this question in generalities. I think the National Water Commission came up with some very strong recommendations concerning study of the rationale behind our current legal water rights to see if they are still applicable in the twentieth and twenty-first centuries. The water laws worked well in the early years, but it seems that there is a growing feeling among concerned people in the water resources field that a fresh look at our legal water rights is called for. Now, whether, in specific circumstances, actions that are now under way are designed to force any such reassessment of legal matters is beyond me. I really don't know.

COMMENT: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. It is a very interesting concept, nonetheless. Mr. Schmidt, do you have another comment?

COMMENT: Mr. Schmidt, SCS Engineers, Long Beach, California. Yes. I wanted to comment on Frank Dryden's statement. Frank is absolutely correct in stating that the farming profession knows a great deal about the application of TDS, sodium, and some of the other common constituents in irrigation water. We were concerned more with the up-take by potable crops of some of these constituents we know less about. In other words, without any question, there will continue to be a great deal of irrigation with reclaimed wastewater, and some of the same questions which are coming up about its use in drinking water may also be of concern in terms of edible crop uptake of these constituents.

RESPONSE: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. I think that we all recognize that. I think Frank meant that it is outside the context of this particular conference perhaps.

COMMENT: Ms. Gorchev, EPA, Washington, D.C. I am not so sure if health effects studies should be given a higher priority than the socio-economic ones. I feel that unless you tell us that this practice would be socially accepted, and that it is economically needed and feasible, there shouldn't be any need to do health effects work.

RESPONSE: Mr. Altouney, Marine Eco Systems, NOAA, Boulder, Colorado. This is a very good point. We have addressed it at length, and I gathered from the discussions that if the health effects were fully studied and understood, our socio-economic problems would vanish. In other words, the feeling of safety that is lacking relates to the health aspects. So, we cannot go around selling a program on which we, ourselves, are not sold. If we fear the health consequences of certain viruses, pathogens, whatever you want to call them, we cannot go around and try to sell it to the people.

So, as a group, we have expressed a concern that increasing amounts of recycled wastewater are going into the system without the full knowledge of the consumers. We felt that we need to do a lot more in the area of health to determine the consequences of using recycled water for potable purposes.

So, I agree with you. It's like the chicken and the egg. However, we feel that the health aspects are probably paramount. We would not suggest that socio-economic research should not be done at this time, although we feel the priority is somewhat lower.

RESPONSE: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. In other words, I think we'll move ahead together.

COMMENT: Mr. Willard R. Chappell, Director, The Molybdenum Project, University of Colorado, Boulder, Colorado. I want to introduce a couple more complications, that perhaps were included in your thinking. At least in the Southwest, a number of things are going to be interconnected with water use. One of those is the energy industry which in this state, and I am sure elsewhere in the Southwest, is likely to be limited by water supply more than anything else. Of course, one also interacts with agriculture in the sense that everything we take out of the Colorado River Basin increases the TDS level in the Colorado River, and we all know that that is a complicated issue as well. So the socio-economic impact is far beyond that of the individual householder and relates to the energy industry and the agricultural industry as well.

COMMENT: Mr. Parker, Brown & Caldwell, Walnut Creek, California. As we are talking about priorities here, I would like to contribute my own rating system to these. I think they fall on the extremes of high priority and low priority. I think Numbers 1 through 6 help to identify for us the potential market for reclaimed water. Why are we standing here talking about reclaiming water if we don't know what the need is? How are we going to sell Congress that they ought to spend $100 million over the next fifteen years if we can't project the need, and predict that we can develop the institutional arrangements for putting reclaimed water into the system?

However, beyond Item 6, I think we are getting into constraint problems--problems that someone has created to research. I think that they are truly ones that we are going to find in individual situations, but I don't think the way those public agencies will solve those problems will be pointed at in an EPA report on some paper study in advance of those problems. My experience has been that when people want to solve that kind of problem, they talk to someone who has solved that kind of problem. So, if we are going to address issues such as the acceptable portion of recycled water, problems faced by cities pioneering reuse, socio-economic aspects of delays, studies of diffusion of water recycling information, let's get case histories on that. This is what is going to be valuable to people. But that is something that is in a long-range time frame. That is going to be after we have practiced reuse. So I would give those the very lowest of priorities in this group.

RESPONSE: Altouney, Marine Eco Systems, NOAA, Boulder, Colorado. Thank you for your comments.

COMMENT: Mr. Milliken, Denver Research Institute, Denver, Colorado. One further comment. I hope it will not be a misunderstanding of our group's comment relating to the paramount priority given health effects. I think it is true that unless health effects ultimately are found not to be a constraint, we will not attempt recycling. But I take a little bit of an issue with Dr. Altouney's comment that if health effects are solved, the socio-economic problems disappear. I don't think they do. I think that is just the beginning. If you remember Elroy Spitzer's comment this morning, he was concerned about the low priority given to aesthetics. There was nothing in the health effects about aesthetics, but aesthetics can kill a bond issue, and that is what is going to pay for the recycling facilities.

So it was certainly my feeling, and I believe it was shared by the group, that we do need to maintain some funding of socio-economic research, even though the health effects are the one critical point.

RESPONSE: Mr. Altouney, Marine Eco Systems, NOAA, Boulder, Colorado. Gordon, I believe the choice of the words "will disappear" was probably bad. Probably it should have said "will be a lot easier to solve."

RESPONSE: Mr. Milliken, Denver Research Institute, Denver, Colorado. That is certainly true.

COMMENT: Dr. Goldsmith, National Cancer Institute, NIH, Bethesda, Maryland. I would like to suggest that the introduction of this new technical procedure, which may effect health on a widespread basis, is not the only time in this generation or this century that such things have happened. It seems to me that we might be more constructive in our approach to this class of problems if we began to catelogue some of the other technical innovations which carried with them a certain amount of fear,a certain amount of public anxiety, and so forth. One could list some of these: the nuclear power, the introduction of some of the pollution control systems on automobiles, even the construction of freeways if you are willing to go back that far. I think we have to take some lessons from this class of experiences.

One of the things that seems prominent to me in this collection of experiences--and possibly fluoridation is nearest to everyone's knowledge here--is that there were conflicts and very real ones between the judgments of scientific and technical personnel and the understanding of the basis of that judgment and acceptability of it. It seems to me we are going to be in the same situation here. We have to deal with the several levels of understanding and perception. It does seem to me, however, that in this one we have a rather strong case in that this is a problem in which the innovation is a gradual one. We have experience in some aspects of water reuse. It is just not quite at the level of potable water reuse. I would make an appeal to stress the parallel experience with other technical innovations which have similar implications for public acceptability.

RESPONSE: Mr. Altouney, Marine Eco Systems, NOAA, Boulder, Colorado. Thank you.

COMMENT: Moderator Robeck, Water Supply Research Laboratory, Cincinnati, Ohio. One last comment.

COMMENT: Mr. Altouney, Marine Eco Systems, NOAA, Boulder, Colorado. I just wanted to comment that the first research project which we developed was developed over some three pages of our report and was not read. But that particular project did try to cover the interrelationship between such things as energy and cooling water uses, and dual water, agriculture, and so forth. I wanted to emphasize that we were not ignoring that economic aspect.

COMMENT: Mr. Heaton, Denver Water Department, Denver, Colorado. Just a comment on Mr. Dean's remark. We are not ashamed of our decision to investigate potable reuse. It is not a bottom-of-the-barrel decision or a last resort to us. It is still one of the most viable, efficient, and logical means we have of increasing our future supply. However, if California were to release its hold on our water, that would be fine, too.

PARTICIPANTS

George W. Adrian
Los Angeles Department of Water & Power
P.O. Box 111
Los Angeles, CA 90051

Edward G. Altouney
Deputy Director, Marine Eco Systems,
Analysis Program
NOAA
Boulder, CO 80302

Michael A. Bellanca
Virginia Water Control Board
P.O. Box 11143
Richmond, VA 23230

Edwin R. Bennett, Assoc. Professor
Department of Civil & Environmental
Engineering
University of Colorado
Boulder, CO 80302

Gerald Berg
Methods Development & Quality
Assurance Research Laboratory
NERC-EPA
Cincinnati, OH 45268

Dolloff F. Bishop
U.S. EPA
National Environmental Research Center
4676 Columbia Parkway
Cincinnati, OH 45268

James R. Boydston
U.S. EPA
200 SW 35th
Corvallis, OR 97330

Carl A. Brunner
EPA, NERC, Advanced Waste Treatment
Laboratory
4676 Columbia Pkwy, Rm. 146
Cincinnati, OH 45268

Gary P. Carlson
Department of Pharmacology & Toxicology
University of Rhode Island
Kingston, R.I. 02881

Willard R. Chappell, Director
Molybdenum Project
University of Colorado, GAMOW 1033
Boulder, CO 80302

Robert T. Christian
University of Cincinnati
Kettering Laboratory
3223 Eden Ave.
Cincinnati, OH 45267

Neil M. Cline, Manager
Orange County Water District
P.O. Box 8300
Fountain Valley, CA 92708

John J. Convery
AWTRL, U.S. EPA
4676 Columbia Parkway
Cincinnati, OH 45268

John T. Cookson
University of Maryland
Civil Engineering
College Park, MD 20740

Gunther F. Craun
EPA, WSRL, Inorganic Studies
4676 Columbia Parkway
Cincinnati, OH 45268

Robert B. Dean
AWTRL, U.S. EPA
4676 Columbia Parkway
Cincinnati, OH 45268

Franklin D. Dryden
Sanitation District of Los Angeles County
P.O. Box 4998
Whittier, CA 90607

Stuart G. Dunlop
University of Colorado Medical Center
4200 E. 9th Ave.
Box B-175
Denver, CO 80220

Beatrice England
San Diego County Health Department
1600 Pacific Highway
San Diego, CA 92101

John N. English
EPA
4676 Columbia Parkway
Cincinnati, OH 45268

Hans L. Falk
NIEHS
P.O. Box 12233
Research Triangle Park, N.C. 27709

Don Felke
Tertiary Plant Foreman
811 E. Las Vegas
Colorado Springs, CO 80947

Russell Fitch
EPA Region VIII
1860 Lincoln, Suite 900
Denver, CO 80203

Lloyd C. Fowler
Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, CA 95118

Lawrence Gallowin
National Bureau of Standards
Building 226, Room B 306
Washington, D.C. 20034

A.W. Garrison
EPA
SE Environmental Research Laboratory
Analytical Chemistry Branch
Athens, GA 30601

Jack Glennon
U.S. Army Medical Research
Development Command
Forrestal Building, Room 8F055
Washington, D.C. 20314

John R. Goldsmith
National Cancer Institute, NIH
7910 Woodmont Ave.
Bethesda, MD 20014

Hend Gorchev
EPA
401 MSR. S.W.
Washington, D.C. 20460

Daryl Gruenwald
Wastewater Treatment Superintendent
811 E. Las Vegas
Colorado Springs, CO 80947

Carl Hamann
Cornell, Howland, Hayes & Merryfield, Inc.
1930 Isaac Newton Sq. E., Room 202
Reston, VA 22090

Paul D. Haney
Black & Veatch
P.O. Box 8405
Kansas City, MO 64114

Richard D. Heaton
Denver Water Department
144 W. Colfax Ave.
Denver, CO 80202

Stephen Heare
Arlington, VA

Carl Houck
Black & Veatch Engineers
12075 E. 45th Ave.
Denver, CO

Roger Jorden, Assoc. Professor
Department of Civil & Environmental
Engineering
University of Colorado
Boulder, CO 80302

Charles W. Lee
Washington University Medical School
VA Hospital
John Cochran Division, Bldg. 3, Apt. E-1
915 Grand Ave.
St. Louis, MO 63106

Cheng-Chun Lee
Pharmacology and Toxicology
Midwest Research Institute
425 Volker Blvd.
Kansas City, MO 64114

R. E. Leffel
Camp, Dresser & McKee, Inc.
One Center Plaza
Boston, MA 02108

Edwin H. Lennette
State of California
Biomedical Laboratories, Dept. of Health
2151 Berkeley Way
Berkeley, CA 94704

K. Daniel Linstedt, Assoc. Professor
Department of Civil & Environmental
Engineering
University of Colorado
Boulder, CO 80302

William Long
EPA
Washington D.C.
5205 Waterview Dr.
Rockville, MD 20853

Leland J. McCabe
Criteria Development Branch
Water Supply Research Laboratory
EPA,4676 Columbia Parkway
Cincinnati, OH 45268

Perry McCarty
Stanford University
Department of Civil Engineering
Stanford, CA 94305

Francis M. Middleton
NERC, U.S. EPA
4676 Columbia Parkway
Cincinnati, OH 45268

[illegible] Gordon Milliken
Denver Research Institute
University of Denver
Denver, CO 80210

Kenneth J. Miller
Denver Water Department
144 W. Colfax Ave.
Denver, CO 80202

Gordon W. Newell
Stanford Research Institute
333 Ravenswood Ave.
Menlo Park, CA 94025

E. M. Nupen
N.I.W.R. C.S.I.R.
P.O. Box 395
Pretoria, South Africa 0001

James I. Ogilvie
Denver Water Department
144 W. Colfax Ave.
Denver, CO 80202

Henry J. Ongerth
California Department of Health
2151 Berkeley Way
Berkeley, CA 94704

Miriam Orleans
University of Colorado Medical School
4200 E. 9th Ave.
Denver, CO

T. Panswad
Graduate Student (former)
4 Mankien 2
Huamark
Bangkok 24
Thailand

Denny S. Parker
Brown & Caldwell
1501 N. Broadway
Walnut Creek, CA 94596

Roland Rautenstraus
President
University of Colorado
Boulder, CO 80302

Charles H. Ris
EPA Industrial R & D
Industrial Pollution Control Division
Office for Environmental Engineering
Washington, D.C. 20460

Gordon G. Robeck
Water Supply Research Laboratory
4676 Columbia Parkway
Cincinnati, OH 45268

Joseph Roesler
EPA-NERC
4676 Columbia Parkway
Cincinnati, OH 45268

William Rosenkranz
EPA
401 M Street, SW
Washington, D.C. 20460

Herbert I. Sauer
Community Health & Extension
Environmental Quality
University of Missouri
307 Watson Pl.
Columbia, MO 65201

Richard K. Schaefer
Washington Environmental Research Center
EPA
R.D. 690
Washington, D.C. 20460

Curtis J. Schmidt
SCS Engineers
4015 Long Beach Blvd.
Long Beach, CA 90807

William Seeger
Kennedy Engineers, Inc.
657 Howard St.
San Francisco, CA

Raymond E. Shapiro
Epidemiological Unit, DHEW-PHS
Food & Drug Administration
200 C Street, S.W.
Washington, D.C. 20240

Hillel I. Shuval
Director, Environmental Health Laboratory
Hebrew University
Jerusalem, Israel

Rexford D. Singer
University of Minnesota
1160 Mayo Memorial
Minneapolis, MN 55455

John M. Smith
EPA, NERC, Advanced Waste Treatment Laboratory
4676 Columbia Pkwy, Rm. 146
Cincinnati, OH 45268

Sheldon O. Smith
Environmental Conservation Programs
Nassau County Department of Health
240 Old Country Rd.
Mineola, N.Y. 11501

Stanley Smith
Water Division, EPA
EPA Region VIII
1860 Lincoln St.
Denver, CO 80203

Mark D. Sobsey
University of North Carolina
Chapel Hill, N.C. 27514

Clive C. Solomons
University of Colorado Medical Center
4200 E. 9th Ave.
Denver, CO 80220

Albert Soukup
U.S. EPA
Denver, CO

Elroy F. Spitzer
AWWA Research Foundation
6666 W. Quincy Ave.
Denver, CO 80235

Otis J. Sproul
Professor of Civil Engineering
University of Maine
355 Aubert Hall
Orono, ME 04473

Marshall Steinberg
Director, Laboratory Services
U.S. Army Environmental Hygiene Agency
Aberdeen Proving Ground, MD 21010

E. A. Swinton
Research Scientist
Australian C.S.I.R.O.
c/o Australian Embassy
Washington, D.C.

Richard Symuleski
National Bureau of Standards
Building 226, Room B 306
Washington, D.C. 20034

Michael J. Taras
American Water Works Assn.
Research Foundation
6666 W. Quincy Ave.
Denver, CO 80235

Robert G. Tardiff
EPA, NERC, Water Supply Research Laboratory
4676 Columbia Parkway
Cincinnati, OH 45268

Graham C. Taylor
Denver Research Institute
University Park
Denver, CO 80210

Vern W. Tenney
EPA
100 California St.
San Francisco, CA 94111

Patrick Tobin
Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

A. C. Trakowski
U.S. EPA
Office of R & D, RD 676
Washington, D.C. 20460

Craig Wallis
Professor of Virology
Baylor College of Medicine
Department of Virology & Epidemology
Houston, TX 77025

Roger A. Weidelman
Division of Planning Coordination
Bureau of Reclamation
P.O. Box 25007
Denver, CO 80225

Rocky D. Wiley
Denver Water Department
144 W. Colfax Ave.
Denver, CO

Harold Wolfe
Director
Dallas Water Research Center
Dallas, TX

Richard L. Woodard
Camp, Dresser & McKee, Inc.
One Center Plaza
Boston, MA 02108

Stephen W. Work
Denver Water Department
144 W. Colfax Ave.
Denver, CO 80202

Robert L. Wortman
Oklahoma State Department of Health
Environmental Health Services
Oklahoma City, OK

Darwin Wright
EPA
401 M Street, S.W.
Washington, D.C. 20460

B. Cees J. Zoeteman
WHO International Reference Center for
Community Water Supply
Parkweg 13, The Hague
The Netherlands